Proceedings of the Sixth Meeting

OF THE

Illinois Water Supply Association

HELD AT

THE UNIVERSITY OF ILLINOIS
March 9 - 11, 1914

Published by the Society

URBANA-CHAMPAIGN, ILLINOIS
1914

Flanigan-Pearson Printing Co.
Champaign, Illinois.

Dept. Ry. & c.
Illinois Univ. Library
5-1-44

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THIRD VICE-PRESIDENT—W. W. DeBerard, Chicago.
SECRETARY-TREASURER—Edward Bartow, Urbana.

COMMITTEES.

EXECUTIVE—
The officers and Past President, C. H. Cobb, Kankakee.

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PROGRAM—
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E. MACDONALD, Lincoln.
JOHN W. ALVORD, Chicago

MINUTES OF THE SIXTH MEETING OF THE ILLINOIS WATER SUPPLY ASSOCIATION.

The sixth meeting of the Illinois Water Supply Association was called to order by President Cobb at 2 P. M. Monday, March 9, 1914, in the Lecture Room of Engineering Hall at the University of Illinois. President Cobb spoke to the members as follows:

Members of the Illinois Water Supply Association: This is the sixth annual meeting of our association, and thanks to our secretary, Dr. Bartow, we keep increasing every year our membership and our usefulness to our members.

I was not present at the time of my election last year so I take this opportunity to thank you for the honor conferred upon me.

I think that the most important measure that we can adopt at the present meeting will be to become a Section of the American Water Works Association as they have kindly invited us. By so doing we will not lose our idenity but we will be strengthened by connection with the national organization.

I hope that our present meeting will be as interesting and instructive as past meetings have been.

The Secretary-Treasurer's report was then presented.

SECRETARY-TREASURER'S REPORT.

Even though no special campaign has been made for members during the past year a satisfactory increase is noted. The continued interest in the Association shown by the water works men of the state and by those from other states is gratifying. The following table shows the number of members and associates at the time of each meeting since the organization of the Association.

	1909	1910	1911	1912	1913	1914
Members	37	116	158	183	240	264
Associates	1	13	19	24	28	31

The numbers shown do not correspond exactly to the number of names which will be printed in the Proceedings, as all who join at the time of the meeting will be included. During the past year 39 new members have been elected, 9 have resigned, one member, Mr. William R. Humphrey, has died, and 6 have been dropped, leaving a net membership of 264, 4 associates have been elected, 1 has resigned, leaving a net associate membership of 31.

That the interest in the Association is widespread is shown by the fact that now 27 states, 5 foreign countries, the District of Columbia and the Canal Zone are represented in the membership.

The Proceedings of the fifth meeting have been edited and published. 1350 copies were printed, including 400 copies bound in cloth for members, associates and advertisers. Paper bound copies have been sent as exchanges to the Illinois Society of Engineers and Surveyors and the Indiana Sanitary and Water Supply Association. The Proceedings of these societies were sent to members who had paid the 1913 dues prior to May 1st. Unless instructed to the contrary the Secretary will again try to arrange the same exchanges for the coming year. With the co-operation of the printer the Proceedings were issued even earlier than last year, being sent to the members during the first week in May. Even better arrangements have been made for this year and it is hoped that the Proceedings will be issued even earlier. Any material not ready on time will be omitted.

Again there has been an increase in the size of the Proceedings. The following table shows the number of papers and advertisements published each year since the founding of the Association:

	No. Papers	No. Pages	No. Ads	No. Pages
1909	15	188	27	16
1910	22	218	48	32
1911	24	194	50	31
1912	29	260	53	35
1913	41	277	59	42

Nearly as many advertising contracts are in hand as were printed in the Proceedings last year.

One thousand copies of an announcement compiled from the 1913 Proceedings were issued and have been distributed to prospective advertisers, prospective members and to libraries that might be interested in the Proceedings. As a result several orders for the complete sets of Proceedings have been received and filled.

The financial statement shows an actual balance of $120.66 compared with an actual balance of $21.30 a year ago. There still remains unpaid $22.00 advertising and $160 dues from 1913 and preceding years, some of which it is hoped will be collected. The balance does not include the 1914 dues which have been paid. The amount in the treasury March 1, 1914, available for expenses following this 1914 meeting is $370.66 compared with $304.31 available a year ago.

FINANCIAL STATEMENT.

Balance, for year 1912-13		$ 21.31
RECEIPTS—		
1913-4, dues, etc. prior to March, 1914	$ 283.00	
Initiation fees—		
Members	42.00	
Associates	30.00	
Dues, Members 1911	2.00	
Members 1912	12.00	
Members 1913	228.00	
Associates 1912	15.00	
Associates 1913	95.00	
Advertising 1911	6.00	
Advertising 1912	10.00	
Advertising 1913	375.80	
Reprints	63.28	
Sale of Proceedings	45.91	
Miscellaneous	16.60	
Receipts March 1, 1913—March 1, 1914	1224.59	
Total		1245.90
EXPENDITURES—		
Postage	55.52	
Express	68.84	
Freight	1.21	
Printing	80.50	
Duplicating	5.45	
Engraving	62.92	
Stenographic and clerical work	65.00	
Printing proceedings	685.42	
Reprints	88.12	
Miscellaneous	12.26	
Total		1125.24
Balance for year 1913-14		120.66
Dues, members 1914	180.00	
Dues, associates 1914	70.00	
		250.00
Balance, March 1, 1914		$ 370.66

The Secretary wishes to acknowledge again assistance given by many members of the Association. He wishes to urge that the Association be brought to the attention of any water works men who are not members. The Association needs them and they need the Association.

Patronize our advertisers. Complaint has been made by only one of those who advertised in the last Proceedings that the investment did not pay.

Suggestions were made that the members of the Association visit the filter plant at Danville or the new plant at Decatur at the time of a meeting. The Association is invited to visit Decatur at the close of this meeting.

Suggestions have also been made that a meeting might be held in the fall in Chicago or some other place at which the members of the Association could get together to informally discuss water problems and possibly visit some points of interest. In Chicago the intakes of the Chicago city water works and the laboratories and works of the Sanitary District would be especially interesting. Let the Secretary know your feelings with regard to these matters.

EDWARD BARTOW,
Secretary-Treasurer.

The Chairman appointed Messrs. Frank Bachmann and C. A. Jennings as a committee to consider the Secretary's report and audit the accounts. The Committee later presented the following report:

The Auditing Committee has audited the Secretary's books. They are found to be correct and we move that the report be adopted.

FRANK BACHMANN,
C. A. JENNINGS,
Committee.

The recommendation was approved.

Professor A. N. Talbot, Chairman of the Publication Committee, read a report as follows:

REPORT OF PUBLICATION COMMITTEE.

The Publication Committee calls the attention of the Society to the active and efficient work of the secretary shown in printing and distributing the Proceedings of the Fifth Meeting so soon after the date of the meeting. The volume contains a large number of valuable papers and it is highly creditable to the Society. The Committee wishes to put on record that the credit for soliciting papers and editing and printing the Proceedings should be given to the secretary. The Committee has had much pleasure in approving the secretary's work on publications from time to time.

Respectfully submitted,
A. N. TALBOT,
W. W. DEBERARD,
Publication Committee.

The report was accepted.

Mr. Paul Hansen, Chairman of the Committee on Exhibits, stated that the exhibits had been arranged for in the usual way.

The secretary read a Report of the executive committee concerning amalgamation with the American Water Works Association as follows:

REPORT OF THE EXECUTIVE COMMITTEE, CONCERNING AMALGAMATION WITH THE AMERICAN WATER WORKS ASSOCIATION.

The American Water Works Association adopted a new constitution at the meeting in Minneapolis in June, 1913. This constitution provides for the formation of local sections as follows:

Article X.

Sections.

Section 1. Local Sections may be established by the Executive Committee on receipt of a written request to that effect signed by twenty Active or Corporate Members of the Association, residing in territory within which the Local Section is desired.

Section 3. Such sections shall choose their own officers and committees and may make any rules for their government not inconsistent with the constitution and by-laws of the Association, but these rules must first be approved by the Executive Committee.

Section 4. Each Local Section may receive from the Treasurer of the Association, for local use, not more than twenty-five per cent of the annual dues paid to the Association by the members of said Local Section. The Treasurer of said Local Section shall forward to the Secretary of the Association his application indorsed by the presiding officer of the Section for such portions of said sum as may be needed; and upon receipt of such application the Secretary shall request the Finance Committee to authorize the Treasurer of the Association to pay such sum to the Treasurer of the Local Section. Said sum may be used by the Local Section only in payment of necessary operating expenses incurred by the section, such as printing, stationery, postage, rent and care of room, light, fuel, etc. At the end of each fiscal year the Treasurer of each Local Section shall certify to the Secretary of the Association the balance on hand of the funds received from the Association. This balance shall be returned to the Association or shall be charged to the Local Section as a portion of its quota for the following year. No Local Section shall be entitled to draw upon the Association until such certification has been made, and its accounts audited by the Finance Committee.

Section 5. The presiding officer of each section shall be an Honorary Vice-president of the Association.

Section 6. Any section may be dissolved by the Executive Committee for good and sufficient reasons.

Later action by the Executive Committee provides for the publication of a quarterly journal in which the proceedings of local sections may be published.

The Illinois Water Supply Association has been invited to become a section of the American Water Works Association. Some of the advantages of union are the following:

Members will receive the Journal of the American Water Works

Association which will include papers read before the American Water Works Association and all of its sections, National and Local.

Members will be privileged to attend meetings of the American Water Works Association and all of its sections.

Those who are now members of the Illinois Water Supply Association and the American Water Works Association will pay only the $5.00 per annum dues of the American Water Works Association. Members of the Illinois Water Supply Association who are not members of the American Water Works Association may join the American Water Works Association without payment of the membership fee provided they have paid in dues and fees to the Illinois Water Supply Association the amount of the membership fee ($5.00) of the American Water Works Association.

By becoming a section of the American Water Works Association the Illinois Water Supply Association will not lose its identity but will be strengthened by connection with the national organization.

Your Executive Committee recommends that the question of becoming a section of the American Water Works Association be submitted to a vote of all members and that in case a majority are in favor of such action, that your Executive Committee be authorized to take the necessary steps to become such a section.

Messrs. Paul Hansen, Dabney H. Maury, and John W. Alvord were appointed a committee to consider the report. They later presented a preliminary report with the recommendation that a report be prepared showing the pros and cons of the question and that this report be submitted for a letter ballot of the members at a later date. After some discussion the report was adopted.

Walter Reid, Superintendent Water Works, Springfield, read a paper entitled "The Efficiency of a Triple Expansion Pumping Engine."

L. A. Fritze, Chemist Moline Water Dept., Moline, read a paper entitled "Removal of Anchor Ice by Means of Air."

C. M. Roos, Manager Water Company, Cairo, read papers entitled "A Standpipe Failure" and "Experiences Following the Flood of 1913". The papers were discussed by Messrs. Maury and Langelier.

C. A. Jennings, Supt. Filtration, Union Stock Yards, Chicago, read a paper entitled "Hypochlorite Treatment Now Firmly Established".

W. J. Allen, Chief Engineer Water Works, Waukegan, read a paper entitled "Experiences with the Waukegan Water Supply". It was discussed by Messrs. Jennings and Bartow. ADJOURNED.

A band concert was given at 4:15 in the University Chapel by the University of Illinois Military Band.

PROGRAM.

1.	March—"National Spirit"	*Hager*
2.	Overture—"Raymond"	*Thomas*
3.	Quartet from "Rigoletto"	*Verdi*
	MESSRS. KIRBY, ROGERS, MCCLELLAND AND POWERS	
4.	"Nights of Gladness"	*Ancliffe*
5.	"By the Swanee River"	*Myddleton*
6.	"Hungarian Rag"	*Lenzberg*
7.	"U. S. A. Patrol"	*Peck*

The second session was called to order at 7:30 p. m. by President Cobb.

John W. Alvord, Consulting Engineer, Chicago, read an illustrated paper entitled "Too Much Water".

Edward E. Wall, Water Commissioner, St. Louis, Mo., read an illustrated paper entitled "The St. Louis Rapid Sand Filter Plant".

Langdon Pearse, Division Engineer, Sanitary District of Chicago, read an illustrated paper entitled "Rapid Filter Plant at Evanston, Illinois". ADJOURNED.

The third session was called to order at 10 a. m. Tuesday morning, by President Cobb.

C. B. Anderson, Illinois State Geological Survey, Urbana, presented a paper entitled "Character of Artesian Well Waters in Chicago and Vicinity". The paper was discussed by Messrs. Pownall, Bardwell and W. F. Anderson.

R. C. Bardwell, Chemist, Missouri Pacific Railroad, Kansas City, Mo., read a paper entitled "Water Treatment for Railroads". It was discussed by Messrs. Ely, Pownall, and Huenink.

In the absence of Dr. Adolph Gehrmann, his paper entitled "Underground Movement of Contamination" was read by Dr. T. J. Burrill of the University. Dr. Burrill made a few remarks after the reading of the paper.

C. D. Tufts, President Centralia Water Supply Co., Centralia, read a paper entitled "How Centralia's Water Supply was Secured".

M. L. Enger, Asst. Prof. Theoretical and Applied Mechanics, University of Illinois, read a paper entitled "Locating Leaks in Water Mains by Means of Water Hammer Diagram".

J. M. Bryant, Asst. Prof. Electrical Engineering, University of Illinois, read a paper entitled "Pumping City Water by Electricity".

A paper by W. R. Gelston, Supt. Water Works, Quincy, and Dr. Edward Bartow, Director of the State Water Survey, was read by E. Bartow, entitled "Relation of Sewer Outfall to Water Works Intake at Quincy". It was discussed by Mr. Jennings. ADJOURNED.

The fourth session was called to order at 2 p. m. by the President.

Officers were elected as follows:

President—H. M. Ely, Superintendent Inter-State Water Company, Danville.

First Vice-President—W. J. Spaulding, Commissioner of Public Property, Springfield.

Second Vice-President—E. MacDonald, Superintendent Water & Light Co., Lincoln.

Third Vice-President—W. W. DeBerard, Western Editor Engineering Record, Chicago.

Secretary-Treasurer—Edward Bartow, Director State Water Survey, Urbana.

Mr. H. M. Ely, Chairman of the Committee on Relations with State Departments, reported as follows:

Your committee on "Relations with State Departments" reports as follows:

Since the last meeting of the Association, The Rivers and Lakes Commission has been reorganized with greater powers and increased funds to investigate and regulate the pollution of streams. Your committee understands that co-operation with the State Water Survey is agreed upon. Your committee trusts that the co-operation will prove successful in thoroughly investigating and regulating conditions along equitable and conservative lines.

Your committee feels that the Association is deeply interested in that very important branch of the work of the commission which concerns the investigation of stream pollution.

Soon after his inauguration, Governor Dunne appointed W. A. Shaw as Engineer member of the Rivers and Lakes Commission, and later transferred Mr. Shaw to the Public Utilities Commission.

It is trusted that in filling the vacancy created by Mr. Shaw's transfer, an engineer member will be appointed as well qualified as Mr. Shaw, and in particular, a man thoroughly experienced in Sanitary Engineering, who can approach in a broad way the varied problems in the field of water pollution and sewage treatment.

Your committee would urge that attention be given by the Association, during the coming year, to proposed legislation to permit cities and towns to finance improvements to Water Works outside existing limits of bonded indebtedness, by creating new special limitations for said purpose, and by making possible the creation of water districts along broader lines than is now possible in Illinois.

Respectfully submitted,

H. M. ELY,
W. E. PARK,
C. B. BURDICK,
LANGDON PEARSE,
Committee.

The report was accepted and adopted.

It was voted on motion of M. L. Enger amended by Professor A. N. Talbot that this Association appoint a committee on fire insurance to collect statistics on rates for fire protection and the methods which are in use in this state for determining such rates and to see whether water works companies and cities are having proper attention and care given to the condition of their water works improvements.

A committee consisting of Messrs. Enger, MacDonald, Maury, O. T. Smith and Spaulding was appointed.

Jay Craven, Indiana State Board of Health, Indianapolis, read a paper entitled "A Sanitary Survey of White River".

David H. Jackson, Lake Forest, read a paper entitled "North Shore Sanitary District". Mr. Jackson asked that a resolution be passed that would show the attitude of the Association toward the organization of the proposed North Shore Sanitary District. A committee was appointed consisting of Messrs. Allen, Talbot and Lewis.

At a later session the committee reported as follows:

Resolved, that the Illinois Water Supply Association endorse the formation of a North Shore Sanitary District in Lake county as a means of attaining concerted and efficient action in solving the sewage disposal problem of the district.

W. J. Allen,
A. N. Talbot,
W. Lee Lewis,
Committee.

Dr. John A. Fairlie, Professor of Political Science, University of Illinois, read a paper entitled "Public Control of Water Supplies in Illinois".

Dr. W. H. Frost, Passed Assistant Surgeon U. S. Public Health Service, Cincinnati, Ohio, read a paper entitled "Sanitary Survey of the Ohio River".

F. E. Herdman, Manager of Water and Light Properties, Waukegan, read a paper entitled "Rates and their Relations to Meters".

A paper by Ralph Hilscher, Asst. Engineer of the State Water Survey, and Paul Hansen, Engineer of the State Water Survey, entitled "Surface Water Supplies of Illinois," was read by Ralph Hilscher.

H. E. Babbitt, Instructor in Municipal and Sanitary Engineering, University of Illinois, read a paper entitled "Value of Mathematics in Economic Design of Some Water Works Details". Adjourned.

The annual dinner was held at the Beardsley Hotel, Champaign, at 6:30 p. m. Covers were laid for about 70. President Cobb presided. Speeches were made by Mayor Browder of Urbana, C. D. Rourke, President of the Urbana Commercial Club, Vice-President Kinley of the University, Prof. J. W. White, Supervising Architect of

the University and by Messrs. Bartow, Spaulding, McGonigale, Amsbary and President-elect H. M. Ely.

The fifth session was called to order Wednesday morning at 10 a. m. by President Cobb.

Lloyd Z. Jones, City Engineer, Galva, read a paper entitled "Detection of Leaks in Deep Well Tubes by Electric Light".

The paper by M. E. Hinds, Asst. Chemist State Water Survey, and Dr. Otto Rahn, Assistant Bacteriologist, entitled "The Death of B. Coli and B. Typhosis in Pure Water", was read by F. W. Tanner, Asst. Bacteriologist, State Water Survey.

The paper by Morris Knowles and Maurice R. Scharff, Consulting Engineers, Pittsburg, Pa., entitled "Relation of Out of Pocket Cost to Rate Making" was read by Mr. Scharff.

Owing to lack of time Professor A. N. Talbot, read his paper by title. "The Iron Removal Plant of the Urbana and Champaign Water Company".

Charles Trimble, Supt. Central Illinois Public Service Company, Robinson, read a paper entitled "Reservoir Well of the Robinson Water Company".

Owing to the absence of the authors the Secretary read the following papers by title:

"Chemical Features of St. Louis Filter Problem", W. F. Monfort, Chemist Water Dept., St. Louis, Mo.

"Remodeled Underdrain System for a Mechanical Filter Plant", Dr. Jesse M. Worthen, Supt. Charleston Light & Water Company, Charleston, S. C.

"The Addition of Inorganic Salts to Culture Media Employed in Water Analysis", E. M. Chamot, Prof. Sanitary Chemistry, Cornell University, Ithaca, N. Y.

"Chemical Standards for the Hygienic Purity of Montana Waters", W. M. Cobleigh, Prof. Chemistry, Montana State College, and Chemist State Board of Health, Bozeman, Mont.

"Necessity for State Supervision of Water Purification Plants", Dr. A. J. McLaughlin, International Joint Commission, Washington D. C.

"The Newly Remodelled Reservoir", John Gaub, Chemist Filtration Plant, Washington, D. C.

ADJOURNED to take trip to Decatur to inspect the new filter plant.

The party was entertained at dinner by the City of Decatur and the Commercial Club and was taken in automobiles to visit the new filter plant and the factory of the H. Mueller Mfg. Co.

The Register for the 1914 meeting contains the following names:

MEMBERS.—Allen, S., Allen, W. J., Anderson, W. F., Alvord, Amsbary, Babbitt, Bachmann, Bardwell, Bartow, Bulkeley, Cobb, Corson, Craven, DeBerard, DeWolf, Dunlap, Ely, Enger, Engle,

Fitch, Fleming, Fritze, Ferguson, Gillespie, Hadden, Hanford, Hansen, Herdman, Herschleder, Hilscher, Hinds, Horner, Housman, Huenink, Jackson, Jennings, Jones, Keeler, Langelier, Lautz, Lawlor, Lederer, Lewis, Malleis, Marquardt, Maury, McGonigale, Mellen, Miller, J. A., Park, Pearse, Pownall, Pratt, Prettyman, Rahn, Reid, Roos, Ruthrauff, Scharff, Schnellbach, Settle, Shoemaker, Sjoblom, Spaulding, Stromquist, Symons, Talbot, Tanner, Trimble, Tufts, Wall, Williams, Wintzingerode.

ASSOCIATES.—American Steel & Wire Co., by E. von Wintzingerode; Birch Valve & Mfg. Co., by Wm. T. Birch; H. W. Clark Co., by H. W. Clark and Dwight P. Childs; DeLaval Steam Turbine Co., by H. V. Peterson; Glauber Brass Mfg. Co., by L. Friedman; Hersey Mfg. Co., by J. J. Strasser and W. B. Cambridge; Marblehead Lime Co., by T. P. Black; H. Mueller Mfg. Co., by E. A. Mann; National Meter Co., by F. J. Bradley and W. A. Gibson; Neptune Meter Co., by Todd Harrison; Pittsburgh Meter Co., by J. M. Wilson.

GUESTS.—Ainsworth, W. I., C. & U. Water Co.; Anderson, C. B., Illinois Geological Survey, Urbana; Bass, G. W., University of Illinois; Broderson, H. J., University of Illinois; Burton, Lawrence, University of Illinois; Chase, Dean, Urbana; Chenoweth, Wm. Casey; Cole, Edw. S., New York City; Eschauzier, Louis, Urbana; Fairlie, John A., University of Illinois; Frost, Dr. W. H., Public Health Service, Cincinnati, O.; Garver, N. B., Urbana; Gordon, F. G., Asst. Engr. for D. H. Maury, Chicago; Hurd, C. H., Indianapolis; Jackson, David H., Lake Forest; Keeth, Grover, Asst. Mech. Engr. Public Service Co., Chicago; Lauter, C. J., Urbana; Lewis, J. E., Urbana; Luckett, W. H., Indianapolis; Newell, C. R., Urbana; Primm, James, Urbana; Rant, Alfred, Urbana; Reilly, R. T., Urbana; Richards, C. R., College of Engineering, University of Illinois; Richards, Keene, Dist. Supt. Public Service Co., Lacon; Ruge, M. F., St. Louis, Mo.; Short, F. E., C. & U. Water Co.; Sievert, C. W., Urbana; Tratman, E. E. R., Engineering News, Chicago; Van Deventer, C. & U. Water Co.; Virmani, D. D., Urbana; Waugh, Dallas, Effingham Water Works, Effingham; Weiland, H. J. Urbana; Wetherill, C. M., Supt. Water Works, Chicago Heights.

THE ADDITION OF INORGANIC SALTS TO CULTURE MEDIA EMPLOYED IN WATER ANALYSES.

BY E. M. CHAMOT.*

For a number of years the author of the present paper and his co-workers have been attempting a systematic study of the culture media commonly employed for the bacteriological examination of potable water, and especially those media to be used in water purification plant control.

It is, I believe, the frequent experience of others also that our so-called standard media are not sufficiently sensitive. They fail to yield uniform results, and not infrequently fail to indicate the presence of organisms lacking in vigor or of strains which we are prone to term atypical.

Upon searching the literature we were surprised to find practically no existing data showing the basis for the chosen concentrations of the various ingredients employed in the preparation of the nutrient media. It is true that statements are found that experimentation was the basis upon which the concentrations were established, but almost never is there found mention of the limits of the concentrations tried, or the limits above and below which it is unsafe to go. The two marked exceptions to this are the proper phenolphthalein reaction and the percentage of gelatine or agar.

The most noteworthy lack of data and experimental proof is in connection with the use of sodium chloride in nutrient media, and it is to this question that much of our attention has been confined.

At the outset, our experimental work was directed to proving that the addition of sodium chloride was without value and probably a detriment. As the work progressed, however, we were astonished to find that not only was it not injurious but a positive benefit. Since these results were obtained, one or two German water analysts have reported that the addition of this salt is beneficial, but no data are given for their findings.

In order to facilitate the study and render it absolutely systematic, the triangular diagram employed by physical chemists in the study of three component systems was employed as a guide, not however as an equilibrium diagram but simply as a scheme to enable us to cover

*Professor of Sanitary Chemistry, Cornell University, Ithaca, N. Y.

all concentrations between those placed at the three points of the triangle. The concentration of any intermediate point being read by the method of Gibbs.

Thus far our completed work has covered dextrose and lactose media; peptone and peptone-meat-broth; liver broth; lactose neutral red; lactose litmus bile-salt; and Harrison's esculine bile salt media. The work is being continued and will be directed principally in the coming year to gelatine and agar media and to so-called synthetic media.

I desire to call your attention in this paper to only one phase of this investigation, namely, the desirability of adding some inorganic salt to the culture media for water examination, in the hope that trial by others may either substantiate or disprove our results.

I ought to add parenthetically that so far as the waters of Central New York are concerned many thousands of separate inoculations have been made of natural and artificial sewages and of pure and polluted waters. The writer has also had opportunity to extend the work to a few Ohio waters, and Mr. John Gaub of the Washington Filter Plant has employed similar methods in his work with equal success.

Since the addition of sodium chloride proved beneficial, other salts of sodium were tried and eventually we carried the investigation to include the chlorides, sulfates, nitrates, phosphates and carbonates of sodium, potassium, ammonium, calcium, and magnesium.

To summarize the results of a vast number of trials, it appears that potassium chloride is most useful in increasing the sensitiveness of the media and insuring uniformity of results. Potassium sulfate takes next rank, then sodium chloride and sodium sulfate. The other salts mentioned above are either of no measurable value or are distinctly injurious when added in appreciable amounts.

A second surprise in this series of investigations was met in the behavior of phosphates. With the possible exception of a double potassium sodium phosphate and magnesium ammonium phosphate even a very slight addition proved to exert an inhibitory effect upon growth. It must be remembered, however, that we are dealing in all cases with media containing Witte peptone which contains sufficient phosphates for the growth of the organisms.

Potassium chloride may be present in a culture medium up to over two per cent. before any inhibitory effects are noticed. Between ½ and 1 per cent. the sensitiveness of a medium is considerably increased. If even better results are wanted the peptone concentration should be increased to at least 3 per cent.

For the rapid detection of fecal organisms we find that media containing 1 per cent. carbohydrate, 3 to 3½ per cent. Witte peptone, ½ to 1 per cent. potassium chloride and having a reaction approximately +1.2 per cent. gives us the most rapid results, and by far more

uniform results as to gas volumes and gas ratios than standard media. It is not an uncommon event to have well defined gas formation visible within eight hours after inoculation.

It is worthy of note that in all our work we have found, as has long been known, that a normal natural water of from 30 to 150 alkalinity is far preferable to distilled water in the preparation of culture media for water examination, and that whenever possible the +1 to +1.2 reaction is best if it is obtained from an unneutralized acidity of the peptone or meat broth than if from an added mineral acid.

We therefore suggest the trial of culture media to which at least 0.6 per cent. potassium chloride has been added in all media where rapid results are needed.

The greater part of the experimental data involved in the study of the influence of inorganic salts has been carried out under my direction by Dr. H. W. Redfield, John Gaub, and C. M. Sherwood, to all of whom I must acknowledge my indebtedness.

NECESSITY FOR STATE SUPERVISION OF PUBLIC WATER SUPPLIES.

BY ALLAN J. MCLAUGHLIN, M. D.*

State supervision of water works plants should not be a nominal duty performed in a perfunctory manner. It should be a very close supervision of the operation of the plant.

In many states there is a lack of law giving the necessary specific authority to the state to control water supplies and even when such law exists in some instances the state officials depend upon the local authorities for results, with few inspections and very little actual control of the water supplies.

Obviously, in large cities like New York, Chicago, or Philadelphia, which are rich enough to employ efficient operators for their plants and competent bacteriologists to make daily analyses, there is no great necessity for close state supervision, but even here the inspection by state authorities has a salutary effect in keeping up the maximum efficiency. It is in the smaller cities and towns, however, that state supervision and control will have its greatest effect. In order to show the crying need of state inspection and control of water plants, certain instances which came under my personal observation may be cited.

The first thought in municipalities when they get away from the "old oaken bucket" is to secure a supply which shall be adequate in quantity. The next public demand is probably for a clear water if the water is taken from a muddy river. It is only in the last few years that the demand for safe water has been made the paramount issue in public water supplies.

Improvement in water supplies which were grossly polluted with sewage has been effected frequently to eliminate the taste of manufacturing wastes. Gradually municipal officials are beginning to recognize the insistent public demand for safe water. Even now, however, with the lessons of our past epidemics before us it is a difficult task to convince many municipal officials that money should be spent to purify a polluted water supply which is adequate in quantity and reasonably clear in appearance. It is obvious that the Water Board

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or Water Works Superintendent must consider the economic side of this question but they should be just as much interested in furnishing a safe water every day in the year as in the heat efficiency developed from their fuel.

The greatest delusion in water supply history is the dream that Great Lakes water needs no purification. Practically without exception the cities taking water from the Great Lakes and their connecting rivers should install purification plants to protect their citizens, yet many of them persist in furnishing polluted water without treatment of any kind. It is not alone in the use of untreated water that disaster occurs. Many cities have plants which are structurally imperfect or inefficiently operated.

Ashland, Wisconsin, is a notorious instance of a small city with a slow sand filter plant and a typhoid fever rate of 315 per 100,00 in 1910. In spite of its lesson the typhoid rate since 1910 has averaged 72 deaths per 100,000. Inquiry as to the improvement following the calamity which befell this city in 1910, elicited the following from the Health Officer:

> "Your letter wanting to know of the changes in our water works system is at hand. Since 1910 a new filter has been installed. This was in the winter of 1911-1912. In the winter of 1912-1913 the intake pipe was taken up and moved and it was shortened about 900 feet. In the early winter of 1912 a chlorine plant was installed and they have been using it ever since *except when the taste and smell of the water became so noticeable, then it would be cut out for a few days until the taste and smell had disappeared.*
>
> "These are all the changes that have been made that I know of and if there is anything more that I can help you with or anything that you want to know that needs looking into, I will be very glad to do it for you."

The "new filter plant" said to have been installed in the winter of 1911 and 1912 did not prevent the winter and spring outbreak, January to April, 1913. The "chlorine plant" which is said to have been in use since 1912, "except when the taste and smell became so noticeable", seems to have been equally ineffective in reducing Ashland's typhoid fever rate.

The idea seems to be prevalent that when a public water supply is finally conceded to be grossly polluted that the installation of a filter plant settles the problem. It is supposed to be a miraculous fool-proof mechanism which will operate itself even while the operator sleeps or goes to dinner. I know of several excellent gravity mechanical filter plants, (and perhaps this type more nearly approaches the fool-proof than any other) which are operated by a kind of a promoted coal-passer or stoker. The only attempt at bacteriological control is

the sending of a sample to the state capital or the state university once or twice a year.

One plant in a small New York town was inspected by one of my Canadian colleagues. It was a mechanical filter plant using alum as a coagulant. The man in charge was using no alum. He said it looked to him as if the alum was unnecessary as the water was pretty good anyway.

Perhaps the least fool-proof of any of the purification processes is the administration of hypochlorite of lime. The dosage of the chemical to be effective without imparting offensive taste to the water requires very careful and skilful attention. Yet commonly there has been an effort to dose the water by set rule of so many pounds per million gallons regardless of the fluctuations in the raw water. The result is that in order to avoid taste in times of low organic content the dose is fixed too low to be effective when the pollution and organic matter increases at certain seasons due to floods or other causes. Cleveland installed hypochlorite and in 1912 the first year of operation had the lowest typhoid rate in the history of the city. In 1913, the tendency to tamper with and cut down the dose became more manifest and there was a sharp rise in typhoid in Cleveland following the spring freshet in the Cuyahoga River. In one of the smaller Michigan cities I asked the stoker in charge how much "hypo" he was using. He said they had been using about 6 lbs. per million gallons but the mayor telephoned him that he could taste the "hypo" and to cut it down. He said he "guessed" he was using about 4 lbs. per million gallons now.

It is to correct these defects that state control is necessary. Those states which have no law covering these matters should lose no time in securing such a law. Where sufficient law exists the function of supervision and control should be exercised by the state with frequent inspections and definite rules and regulations covering the needs of each municipality. Defects in construction or operation could be thus corrected and efficient maintenance and operation secured. Daily bacteriological control is a necessity and should if possible be carried out in the plant itself.

The greatest obstacle to proper operation and control of plants has been the difficulty of securing the right man to place in charge of the plant. The best type of man for this position is a graduate in sanitary engineering. He will not only be conversant with the mechanical details of the plant, but will be able to adjust his chemicals according to the constitutents and needs of the raw water. Most important of all, he will be able to make daily bacteriological examinations to determine the efficiency of purification. Nearly all the disasters due to sewage polluted water supplies which have occurred were due to lack of daily bacteriological knowledge of the public

supply or the inefficient operation of plants by unskilled men. Personally, I believe the employment of such a graduate is economy even in small cities. I can conceive, however, of cases where it is impossible for economic reasons to pay the necessary salary. In these cases local men must be employed, and trained to do the work. Here the State Board of Health, or as in Illinois the State Water Survey, will find a very useful function. The State authorities could supervise the installation of a small, inexpensive laboratory equipment in small plants and give instruction to the local man in making the necessary water examinations. Whenever possible, however, young graduates of sanitary engineering schools should be employed. Such men are well worth their salary considering the saving in the economical adjustment of chemicals and fuel costs made possible by intelligent supervision. The greatest asset to be credited to skilled operation is the saving of human life effected and the satisfaction of knowing that safe water is being furnished every day.

A STANDPIPE FAILURE.

BY C. M. ROOS.*

The standpipe of the Cairo Water Company, Cairo, Ill., which fell Feb. 11th, 1913, was constructed in 1885 by W. B. Maitland & Son, Contractors, then of Peoria, Ill. It was 16 feet in diameter, the bottom plates of which were ¾ inch, tapering to ¼ inch at the top plates, and the original height was 150 feet. During the year 1900, fifteen years after the standpipe was constructed, the city required the water company to add 25 feet to the height of it, which made the total height above foundations, 175 feet.

The soil conditions where the structure stood are somewhat out of the ordinary, consisting of clays of varying composition for a depth of about 18 or 20 feet, under which for a great depth is a very fine sand. The Ohio River flows within about 100 feet of the standpipe site, the levee separating them, and the current of the river flows directly against the section of the embankment opposite this spot.

Excavation to a depth of about 10 feet and 24 feet in diameter was made in constructing the foundation. Piles 35 feet in length were driven on 2-ft. centers, and were cut off at the original ground surface. The excavation around the piles was filled with concrete, on top of which were six courses of Bedford stone, tapered from 24 feet in diameter at the bottom to 19 feet at the top.

The standpipe during its life of 28 years had withstood without any apparent damage several earthquakes and some strong wind storms. The steel had been carefully scraped and painted regularly every year or two, and while it showed considerable corrosion and pitting, it had not deteriorated seriously at any point with the exception of the section which originally formed the top of the structure.

At 2:15 in the morning, while full of water, with a wind of not over 4 miles per hour, the standpipe fell without warning, in the only direction it could have fallen without causing very serious damage. It fell in the opposite direction from the plant proper, and parallel with the boiler room.

The damage to the pumping station was caused largely by the flow of water and the kicking back of the heavy masonry in the

* Manager Cairo Water Co.

Fig. 1. Loss of Standpipe at Cairo.

Fig. 2. Injury to Buildings at Cairo.

foundation. Fig. 1. See Figs. 1 & 2. The extent of the damage was as follows: sides of boiler room completely demolished, allowing roof to rest on steam pipes; machine shop destroyed with most of the machinery and tools; side walls of high duty pump room torn out, stripping pumps of oil feed cups and small connections; the 16 inch connections from pumps to city mains broken; body of a 16 inch flanged gate valve cracked; the roof and about 3 feet of top of clear well torn off; side walls of filter plant broken in; sedimentation tank of 72,000 gallons capacity damaged to such an extent that it collapsed within a few weeks; two freight cars on tracks near plant completely demolished;

Fig. 3. Section of Standpipe across Levee.

several cottages near plant swept off foundations. See Fig. 3. No lives were lost and no one was injured.

Little or nothing could be done toward supplying the city with water again until about six o'clock in the morning, as the private electric light plant was put out of commission. By three o'clock in the afternoon of the same day, or about twelve hours after the accident, the water was again being pumped into the city mains.

Many theories have been given as to the cause of the accident. The direct cause for the failure at the particular time is not known

and cannot be known. There are several causes to which the failure can be attributed. The piling in the foundation was allowed to extend to the original surface of the ground, and although protected by heavy masonry, it was exposed to a certain extent which resulted in its deterioration. The fact that an additional section of 25 feet was riveted on the top of the structure after it had stood for 15 years, could be the cause of weakening it. The generally accepted cause for the failure at the time that it fell is that the long continued floods in the Ohio River had a tendency to soften the earth in the immediate vicinity of the standpipe and weaken the foundation.

DISCUSSION.

Maury: I should like to say a word of commendation for the water works authorities for having been able, in the face of the disaster which resulted from the failure of the standpipe, to renew service to the city so promptly. I was in Cairo a few days after the standpipe fell. A great deal of damage had been repaired by that time, but there were enough evidences to show that unless the management had been exceedingly active, days might well have elapsed instead of a few hours, before service had been renewed.

EXPERIENCES FOLLOWING THE FLOOD OF 1913.

BY C. M. ROOS.*

Following closely the standpipe failure in the spring of 1913, came the greatest flood in the history of the Ohio Valley, the water registering nearly 55 feet on the government gauge at Cairo. Conditions in Cairo during the flood of 1913 were serious, but in many respects the reports that were spread over the country were greatly exaggerated. Neither time, money nor energy were spared in fighting the waters coming down the Ohio, but at no time during that great flood did the men of Cairo feel that they would lose out in the fight.

Situated at an exposed point between the two greatest rivers in the country, but fortified by the greatest levee system in the world, Cairo became the headquarters during the very height of the flood, from which were sent out relief excursions in every direction to assist those who were exposed to the torrents rushing down the valley. When the waters finally subsided, Cairo stood out as the only city or town along the entire Ohio Valley that had not been damaged by overflow. Since the flood of 1913 a greatly improved levee system has been built at a cost of over $1,000,000, and Cairo now fears flood no longer.

Supplying a city with water during a time like the 1913 flood necessarily carries with it considerable responsibility when conditions other than flood conditions are normal. It happened during the spring of 1913 that many things came up which made the work of the water man anything but agreeable.

After having secured an ample supply of chemicals in anticipation of being cut off from the outside world for a period, and to insure a supply of well treated water during the flood, it was with extreme difficulty that the railroad company could switch the cars to the water plant on account of the congested conditions of their tracks. After the cars were finally switched to the plant, and before they could be unloaded, a hurried order came for the railroads to run every car possible out of Cairo. The result was that the supply of chemicals was rushed out with other cars, and the water company was left with a very limited supply with which to treat an extremely turbid water

* Manager Cairo Water Co.

for the entire service of the city. A supply of chemicals was finally secured by boat from St. Louis after considerable delay.

With the exception of annoyance at times by drift damaging the suction strainer, floods do not directly interfere with the operation of the water plant. When the water is at zero on the gauge, we are required to lift it 20 feet with the low service pumps, and when the water reaches the 54 foot mark we have it 34 feet above the pumps.

An unfortunate condition which caused the water company considerable annoyance during the flood was the collapse of about 500 feet of a defective reinforced concrete sewer in one of the main streets of the city. A 12″ water main was carried down with the sewer with the result that a section of the city was necessarily without water. The water main was at first suspended on steel rails, (See Fig. 1.), but later, after this plan proved unsafe, a section of the

Fig. 1. Section of Street where Sewer Started to Collapse.

main was broken out and the water was by-passed with the result that the entire city was supplied with water again.

During the 1913 flood, representatives of the State Water Survey were in touch with the entire flooded district of the lower part of the state. They made their headquarters at Cairo, coming in and going out on boats. They rendered valuable assistance to the Cairo Water Co. at the time, and it was under their supervision that we installed our first hypochlorite of lime plant. Since the installation of this plant we have installed a permanent plant from which we get very good results.

Under the direction of the State Water Survey a new modern laboratory has been fitted up at the Cairo plant (See Fig. 2). Among

Fig. 2. Laboratory at Cairo.

Fig. 3. New Steel Tcwer and Tank.

other improvements made since the 1913 flood are a new steel tower and tank, (See Fig. 3.) a new wash water system to take the place of washing with standpipe pressure, a new retaining wall (See Fig. 4.) on the inside of the levee between the plant and river; and a new low lift pump of 6,000,000 gallons capacity together with condensing outfit

Fig. 4. A Stone Wall Built to Protect Inside of Levee.

for both low lift and high duty pumps have just been contracted for.

Plans for the future consist of a complete new filter plant of 6,000,000 gallons capacity, which will include sedimentation basin, filters, clear water reservoir, chemical tanks and feeding devices, blower and wash water pump, etc.

DISCUSSION.

Maury: Mr. Hansen, who was one of the officers of the State Water Survey and who rendered such good service during the flood in Cairo, might be able to contribute to the discussion.

Hansen: It is true I was down there and had charge of the work during the flood but Mr. Langelier had more intimate contact with the proposition. You might call on him to describe the hypo treatment.

Langelier: Inasmuch as the water did not rise sufficiently high to overtop the levees surrounding the city, the problem at this point was mainly that of safeguarding the water supply. The filters were not producing a clear effluent, which, of course, indicated low bacterial efficiency. Hypochlorite treatment seemed advisable and a plant was hurriedly installed. Two alcohol barrels were used as storage tanks and two half barrels were used, one as a mixing box and the other as an orifice box. The hypochlorite was obtained from various

sources, but principally from public and private laundries. Shipments of hypochlorite had been made by the Survey, but as the city was cut off from all railroad connections, it was impossible at the time to obtain same. The material obtained from the laundries varied very much in strength, but the quantity applied to the water was accurately controlled by testing each tank of solution for available chlorine. The material required for testing the bleach was a part of the equipment carried by all of the Survey representatives engaged in this work.

The more or less antiquated or inefficient features of the filter plant were noted and recommendations were made to the company. From our point of view Mr. Roos deserves much credit for the manner in which he is carrying out these recommendations.

A SANITARY SURVEY OF WHITE RIVER.

BY JAY A. CRAVEN, C. E.*

To enter into a complete discussion of the work done on the Sanitary Survey of White River in the summer of 1913 by the Indiana State Board of Health would probably try the patience of a good many of the members, interested in other phases of water works. To avoid this, I will give in brief form an outline of the work done and follow this by a short discussion of one topic.

White River, from its source to its mouth, is nearly four hundred miles in length. Its watershed, about two hundred and seventy-five miles in length extends from five to forty miles from the river bed on either side of the stream. The area embraced is about five thousand and thirty-four [5034] square miles, approximately one-seventh of the area of the State. The stream has its headwaters in Randolph County near Winchester. It flows westwardly about eighty-five miles then turns abruptly to the southwest until it flows into the Wabash just above Mt. Carmel, Illinois.

Randolph County is the highest section in the State. The elevation above tide at the source of the river is 1175 feet and at the mouth about 375 feet. This gives an average fall in the river of about two feet per mile, much greater than that of the Wabash River, and about double that of the Ohio River.

The methods used in travelling to collect samples might be of interest. The houseboat used the previous year was brought up the river as far as Martinsville, located about forty-three miles below Indianapolis. The shallowness of the water prevented travelling up river any farther. From Winchester to Martinsville, a distance of 168 miles, the river was traveled in three ways, from Winchester to Muncie on foot, from Muncie to Indianapolis in a rowboat and from Indianapolis to Martinsville in an automobile. The laboratory at Indianapolis was used for the analysis of samples collected, on this portion. At and below Martinsville, all work was done in the houseboat laboratory. This boat, 13 feet wide and 40 feet in length had two rooms, one of which was used as a laboratory, and the other for living quarters.

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In the study made of the river, special attention was given to the following features:

1. The general features of the drainage basin.
    - A. Topography and geology.
    - B. Principal tributaries.
    - C. Gradient.
    - D. River stages and river flow.
    - E. Precipitation.
    - F. Population on water shed.
2. Water works systems.
3. Sewerage systems and sewage disposal.
4. Disposal of garbage and night soil.
5. Manufacturing wastes.
6. Oil well wastes.
7. Typhoid fever.
8. General sanitary condition of cities and towns.
9. Chemical and bacterial analyses of
    - A. Samples from White River.
        - 1. Including cross river and samples from varying depths.
    - B. Samples from tributaries.
    - C. Samples from cities and towns.
        - 1. Public.
            - A. Surface supplies.
            - B. Ground water supplies.
        - 2. Private.
            - A. Wells.
            - B. Springs.
            - C. Cisterns.

The topic selected for a short discussion is the analyses of the private supplies and the results obtained. Five cities and towns will be considered, all of them located below Indianapolis. Slides to depict the results graphically and others to show some of the causes of pollution will follow.

At Martinsville, fifty-nine samples from dug and driven wells were analyzed. Of this number thirty-eight or sixty-five per cent. were good, ten were bad and eleven of doubtful purity. All wells in the eastern part of the city were good, with but one exception. They are all deep wells and the surroundings were good. The water from the well shown in Fig. 1 was used for drinking purposes until the odor and taste became too bad. The two closets are less than ten feet from the well.

In the other half of the town the wells were shallow and located on the low flat bed of the river valley. This too, was in the poorer section of the town, owned by two or three landlords. Only such improvements as were actually needed were made. The wells in most of the places were poorly cared for.

At Gosport, forty-seven samples were collected, and only five or

about ten per cent. were good. Thirty were bad and five were of doubtful quality. Five samples from cisterns were analyzed and only one of these was good. As the quality of the water in the cisterns depends upon the care given it by the owners, little attention was paid to this class of water. Of the forty-seven, five were from

Fig. 1. Well at Martinsville.

deep drilled wells, four of which were good, and one of doubtful purity. Of two springs sampled, one was good and one was bad. The remaining samples were all taken from dug wells, and in many cases very little water was found in the wells, because of the exceptionally dry season. The accompanying map shows the location and condition of wells, springs and cisterns analyzed at Gosport. Fig. 2.

Gosport is located on a high limestone bluff, and the dug wells are connected under ground. When one owner cleans his well, it muddies the wells east of him or those lower on the ground water flow. The town spring located at the foot of the bluff was noted for years as a fine cool water for drinking purposes. Our analysis

showed it to be bad. This is not surprising however, as it was learned that the water from the spring was very muddy at times when wells located on the hill above it were being cleaned. The wells being so connected, is it any wonder that the water supply is bad, as sewage can easily find its way into the private water supplies through similar passages in the soft limestone. The great benefit of the investigation at this point can readily be seen by the fact that two of the citizens commenced the drilling of deep wells when their dug wells were found to be bad. They were advised that the deep well supply was the safest.

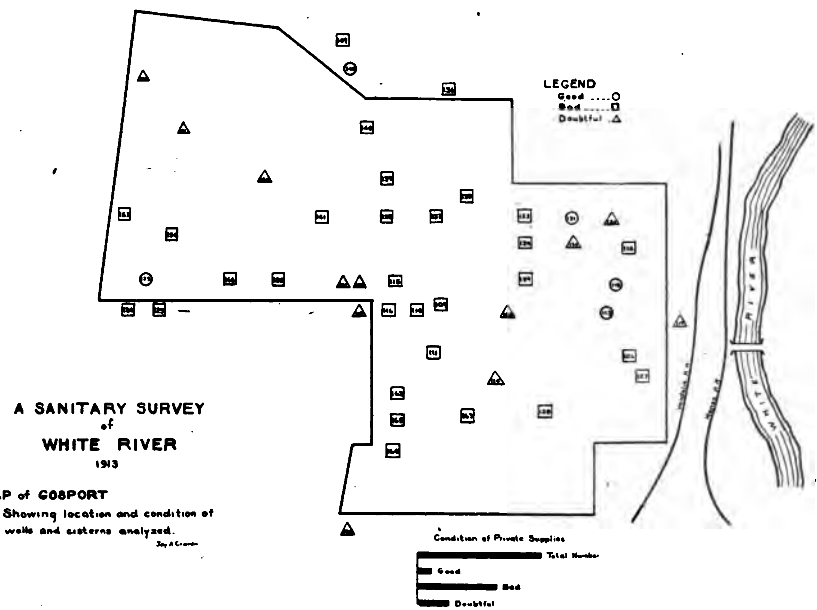

Fig. 2. Map of Gosport.

At Worthington, forty-seven samples were collected and thirty-one or sixty-six per cent. were good. Ten samples were found to be bad and six of doubtful purity. The high percentage of these good samples was due to the campaign of several years before, against the unsanitary conditions of the town, in which special attention was paid to the wells and many of the bad ones were closed.

Eighty-three samples from dug wells were collected at Washington, Fig. 3, and only twenty-five or thirty-one per cent. were good. Forty-three were found to be bad and fifteen of doubtful purity. In many cases wells were dry and no samples could be collected, and in others where samples were taken, there was but little water in the well. These wells undoubtedly were fed by many available sources, which in many cases would be cesspools. Attention is also called to the

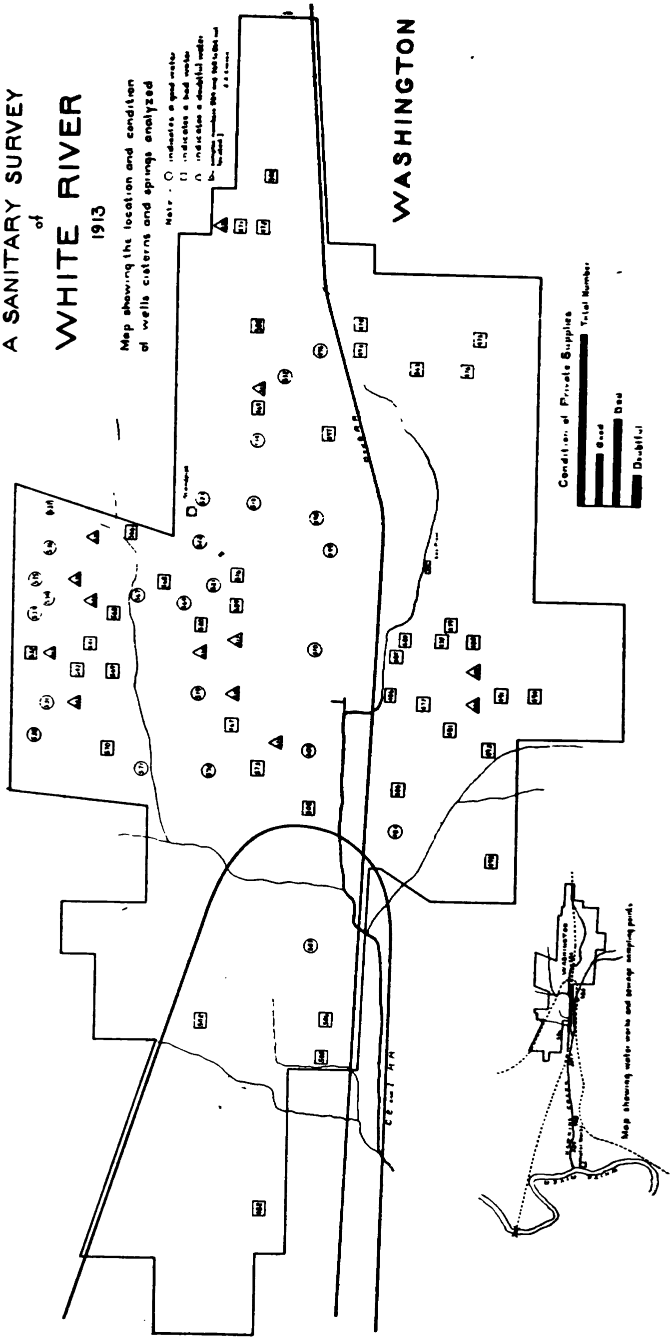

Fig. 3. Map of Washington.

"sewer" system of the town which consists of several branches of a creek. This receives the sewage and other wastes of a large portion of the business district and some of the residence district. It is believed that some water found its way from this ditch to some of the nearby wells and aided in the pollution of them. Fig. 4 shows one variety of convenience. The privy is eight feet from the well and ten feet from the kitchen door. The floods of the preceeding spring washed out a deep hole around the pump of this shallow driven well, and the family found it such a convenient place for rubbish that they did not try to fill it otherwise.

Fig. 4. Well at Washington.

At Petersburg, twenty-nine samples were collected, twenty-eight from wells and one from a cistern. The cistern water was bad. Of the twenty-eight wells, twenty-one were dug wells, and but one was good. Eighteen of them were bad and two doubtful. Here, as at Washington, the ground water was very low due to the long drought, and many of the wells had but little water in them.

The value of these well investigations in the cities and towns depends upon the activities, in many of the cases, of the local health officers. Many of them are interested in the wellfare of their cities and towns, and will take active steps towards the elimination of the bad supplies. Again, it is found that the sole interest of many of them lies in the few dollars received each year, and although the results of the work were turned over to them in all cases, it is doubted if active steps were taken by some of the health officers after a report

was made to them. In such cases the benefits were nil, but where health officers were active and families were not indifferent to their own welfare much good was done. Steps were taken at the time to explain the nature of the work, the necessity of pure water supplies and the harmful results that would undoubtedly in time follow the use of impure waters. As was stated before, many families took active steps at once and new deep wells were being drilled in many cases but a short time after the inspection of the supplies.

One instance might be cited of an old health officer in one of the small towns before mentioned. He said that he had been drinking the water from a public well on the corner nearest him for thirty-seven years, and he had found no ill effects from its use. This well, by analysis, was found to be bad. With such men to lead in the health of the community, is it any wonder that it takes a serious epidemic, due many times to bad water supplies, before the people will take action in their own interests.

HOW CENTRALIA'S WATER SUPPLY WAS SECURED.

BY C. D. TUFTS.*

Citizens of Centralia now proudly claim that their city has the best supply of water for all purposes of any city of its size in Illinois. In addition to the present supply there is an available reservoir capacity of equal size in reserve which may be drawn upon in case the growth of the city should make this enlargement necessary. Prior to the construction of this new reservoir, we knew, though we didn't brag about it, that Centralia had the poorest water supply of any city in the state. The story of how this change was brought about illustrates the fact that any community can accomplish whatever it is compelled to accomplish. The impelling force behind the solution of the water problem in Centralia was not, "We should," "We can," "We will," but it was "We must."

Some twenty years ago the city took over a pumping plant of the Illinois Central Railroad located on Crooked creek, two miles north of the city, and established a city water works. The Illinois Central, being the largest consumer of water, secured a twenty-year contract under peculiar terms which fixed the price paid at approximately one and three-quarters cents per 1000 gallons for water pumped two miles. The creek from which we obtained water derived its name from its tortuous, winding course, but in so far as the word "crooked" implies pollution and corruption, the water of the creek fully lived up to its name.

More than that, this creek raised the wet and dry question every summer, instead of every two years as the law provides. It is hardly fair, however, to call it a question, for in the last few years there never was any question but that Crooked creek would go dry. It was not a local option issue, but a certainty.

The municipality was unable to raise funds to secure an adequate supply, on account of the unusual cost, and the constitutional limitations. The council, as well as the people, were unwilling to turn to a private corporation, the chief objection being that the most important industrial dependence of Centralia is the Illinois Central Railroad, with its extensive shops and terminals, which we feared would not be willing to pay the water rates that might be charged by a private

*President Centralia Water Supply Co.

corporation. No local capitalists were to be found willing to take over the water business and guarantee low rates, and we could not expect outside capitalists to load themselves up with our unfortunate predicament. When you have a dead horse to dispose of, buzzards are the most active bidders.

So, confronted with an imperative demand, the city council was totally lacking in both the concerted energy and the tools and materials necessary for the task before it. In this predicament, Mayor Frazier called a meeting of citizens in the summer of 1909 to unload on them the water problem. In that meeting a committee of seven was appointed and given full authority to devise and carry into execution plans to provide an adequate water supply. After several months of preliminary skirmishing the committee decided to follow a plan of financing a supply that had previously been adopted in Mattoon under somewhat similar conditions. Prof. G. C. Habermeyer, of the University of Illinois, was employed by the city on the committee's recommendation, to make surveys and recommend a suitable site. He recommended a site comprising the valley of two streams emptying into Crooked creek, some eight miles east and up-stream from the pumping station. This site is located in Raccoon and Salem townships, and two of the members of our committee having been Raccoon township products, they were able to support Prof. Habermeyer's scientific deductions by the practical recollection that in their boyhood days they had been able to swim a horse across this valley after heavy rains. It is easy to imagine what effect this story would have on a committee traveling the hot and dry sands of the desert and seeking an oasis.

Following the recommendation of Prof. Habermeyer, the committee employed Mr. E. F. Harper of E. St. Louis, to make preliminary surveys and estimates of capacity and cost. He reported that a dam 800 feet long and thirty feet high would impound a body of water twenty-four feet deep at the dam and approximating one billion gallons. The submerged area was estimated at 250 acres, and the water shed eight square miles. A spillway 150 feet in length was provided, and about eight miles of twenty-inch wood conduit following the creek bottom all the way. The estimate of cost, necessarily only approximate, was $125,000. Up to this time it had been considered absolutely impossible to raise by public subscription in Centralia an amount in excess of $25,000. Yet, the spirit of "We must" had taken possession of the committee, and it settled into the harness with dogged determination.

A stock company was organized, capitalized at $150,000 and an agreement entered into with the city council on the terms of a contract under which the city obligated itself to lease and operate the reservoir and pipe line, and to purchase same at its exact cost. The

revenues of the water department were pledged to pay six per cent. interest on the amount expended, and the city also obligated itself to issue $50,000 in bonds in part payment of the purchase price, and to issue $10,000 of new bonds each year, so as to make an annual payment on the balance. The contract further provided that the city is to levy $10,000 in general taxes each year to pay off that much of the original issue of bonds, so that the original amount of $50,000 stands with $10,000 paid off and $10,000 issued each year. This roundabout method is necessary on account of the legal limitations as to issuance of bonds and taxation.

With this agreement between the city council and the company, the next thing was to get the money. The committee called in the presidents of the two banks and made out a list of "prospects," setting opposite each person's name an amount that in the combined judgment of the committee and the bankers he could afford to subscribe.

The banks consented to take the notes of these persons without other security than the company could furnish. The plan was to ask them to subscribe certain sums to the capital stock of the company and to assure them that the company would obtain the money on their notes without calling on them to do more than sign. The shares of stock signed for were deposited with the banks as collateral security, and the banks furnished the money necessary for the construction.

The list of names started with $5,000 and from that on down to $1,000. No subscription was taken for less than $1,000. The list was made up one Saturday afternoon, and the chairman of the committee announced that the capital stock must all be subscribed the following week. If he had said the reservoir must be constructed the following week the other committeemen would not have had any greater doubts as to his sanity, but they forebore calling a sanity commission and went to work.

On Monday afternoon the newspapers contained leading articles explaining and encouraging the project and carried at the head in good-sized type the names of those who had subscribed $5,000. Not how much each man had subscribed, but the names of those who had subscribed $5,000. We did not call on any to subscribe the first three days, but those on the $5,000 list, and we refused to accept from any of them a subscription for less than $5,000. Each day we published the names of all who had subscribed $5,000 with a story of the progress of the campaign. Our method was so effective that before we had finished with the $5,000 list, several who were on for less sums voluntarily came forward and signed for $5,000. On Wednesday we were obliged to lay off on account of a funeral, but on Thursday night we had eighteen $5,000 subscriptions. By that time we had the ground broken for quick work on the men of lesser

means, and when we quit work Friday night we had $133,500 subscribed, which at that time we hoped would be sufficient. There were fewer than forty subscribers.

In order to understand the task that confronted the committee it must be understood that never before had an individual subscription to a public enterprise been made in Centralia of more than $1,000, and never before had an attempt been made to raise more than $25,000. It was only the spirit of "We Must" that made it possible to raise $133,500 in four days.

Then the Illinois Central had to reckoned with. The contract of the company which fixed the price of Crooked creek water at one and three-fourths cents per 1000 gallons had three more years to run. It was impossible for the city to meet its new obligations to the Centralia Water Supply Company unless the railroad company would make a new contract at a fair rate. When the representatives of the city and the water company walked in on Vice-President Park and informed him a rate of six cents would be demanded, he was somewhat startled, but remembering the horrors of the previous drouths, he told us to go ahead.

The bond issue of $50,000 had to be submitted to vote of the people, but that gave us little trouble. The knockers went about figuring how much each of us would graft out of the cost of the reservoir, but we had the consolation of the knowledge that about 75 per cent. of the public opinion concerning grafting is the result of an unsatisfied longing for a chance to graft, and that did not bother us much. As a matter of fact, we undertook all the responsibility and the mental, moral and financial hazard of financing and constructing a project which finally cost $158,000, and no officer or director of the company received a dollar of compensation either directly or indirectly. Even the lawyers in the company gave their professional services without charge. You can see from this what wonders the spirit of "We Must" can work when it gets going under full steam.

The farmers who owned the land needed for the reservoir suddenly became as much opposed to having a reservoir in their midst as if we were intending to compel them to take a bath in it every morning. They held indignation meetings at the country school houses, and threats were heard that when we went out to dicker for their land they would meet us at the township line with shot guns. The land was worth $40 an acre, but at the school house meetings a price of $150 was fixed, and nearly all the owners joined in an agreement to have that much or die in the attempt. The company had the legal right to condemn, which the farmers knew, but fortunately for us, they didn't know that if we had been compelled to condemn we would be delayed so long we could not get the dam constructed in

time to catch the next spring's rains. This would have meant another year of drouth for Centralia, which would have cost the city more than all their land was worth. We secured one tract for $65 an acre, then went after the owner of the land needed for the dam, and closed with him for a price slightly higher. After that we felt easy, as we could let the contract and start the work, then if we happened to submerge some land before we had acquired it, there would be no damages greater than the value of the land. Every acre of land required, the pipe line right of way, and every necessary settlement was secured without any litigation whatever. This illustrates another point: if your lawyers are working without compensation, it is rarely necessary to go to court. We paid $65 an acre where we took only what we needed and $50 an acre where we were compelled to take the entire farm. One farmer assembled himself, his wife and three children about us, and they all cried in concert at the thought of leaving their old home. How much rehearsing they had done we never learned, but we were so little affected by the exhibition of grief that the farmer was at length obliged to accept $50 an acre for his farm and got nothing for their tears. Then he bought another better farm for the money we paid him, and now if he was obliged to go back to his old home he would have a right to shed tears.

The bond brokers would not take the bonds issued by the city in part payment on the contract, on the ground that no such transaction had ever run the gauntlet of the Supreme Court, and the lawyers would not hazard a guess as to what the court of last resort would do to our plan if it got hold of it. The company took the bonds and held them in its treasury as assets for security of its stockholders and the banks that had loaned the money on their notes. After the work was completed and accepted by the city, the local banks took the bonds and credited the $50,000 on the stockholders' loans. In addition there have been three payments of $10,000, thus reducing the indebtedness of the city to the company to $70,000. The total cost was $158,000, but there were several items of income which reduced the actual net cost to $150,000. The city now pays six per cent. on $70,000 and this money is paid to the banks which hold the notes. Quite a large proportion of the stock is now held, however, by subsequent purchasers who have taken it as an investment. These were people whom we couldn't get within a mile of when we were trying to get the stock subscribed in the first instance.

The work of construction of the dam and the pipe line, and clearing of the reservoir site was begun in the early fall of 1910, and completed in time to catch the spring rains of 1911. The water has a natural fall of about twenty-five feet beside the depth in the basin, which carries it by gravity through twenty-inch wood pipes to the pumping station, where it is delivered direct. A small reservoir near

the pumping station, which was a part of the old system, was connected with the main conduit by a sixteen-inch pipe, and is used as a reserve and an overflow. It is so connected that by opening all the valves water will flow into it from the large reservoir, as well as to the pumping station. By closing a valve in the main conduit, the entire supply may be obtained from the small reservoir. This is sometimes advisable after heavy rains have increased the turbidity of the water in the large reservoir, as the water shed of the small reservoir is so limited it is but little affected by rains which make quite a distinct impression on the main supply.

At times of heavy rains, there has been a flow of fully a foot of water over the spillway of the large reservoir, and Centralia is now certain to enter upon a dry season with a depth of twenty-four feet at the dam. Up to this time the surface of the water has never gone below eighteen feet at the dam, notwithstanding the consumption of the Illinois Central has more than doubled since the company has rebuilt its terminal and shops in Centralia. This new work of the railroad could not have been undertaken at Centralia unless a dependable supply of water was assured, and its importance may be realized when it is stated that the new work of the railroad at Centralia has meant an expenditure up to the present time of two million dollars, and a very considerable increase in the working force.

There was much trouble with leakage in the wood pipe for the first year, but the leaks were finally all closed, and for a year now there have been no complaints. The leakage never did have any effect on the supply of water.

The revenues of the city water department were more than doubled with no material increase in the cost of operation. When the original system was installed, the city authorities, without looking to the future, issued bonds and laid the service pipes without a special assessment. This policy has been followed since, and there have been very few extensions of the water mains. Now the water department has a profit of from $1000 to $1500 a month, and the water mains are being extended to meet the demands of outlying property owners.

The next step will be to add to the system a sanitary filter, which is greatly desired by the water consumers. The mayor and the council strongly favor the installation of an approved filter plant, but again the trouble is to get the money. So far the compelling spirit of "We Must" has not taken possession of our people in regards to the filter, but some day it will, and Centralia's water supply will be perfected.

THE PREPARATION OF STANDARDS FOR THE DETERMINATION OF THE TURBIDITY OF WATER.

BY FRANCIS D. WEST.*

The principle used for the preparation of Turbidity Standards as given in the Reports of the Committee on Standard Methods of Water Analysis of the American Public-Health Association 1905 and 1912; i. e., that of correcting a standard determined by weight by the use of a field method is like hitching the cart before the horse.

No two laboratories nor any two persons in the same laboratory working independently in the preparation of silica standards, following the procedure outlined will make standards exactly alike.

A field method is never accurate and the description of what is "An observation in the middle of the day, in the open air, but not in the sunlight etc.," is a source of many possible interpretations. The amount of light, the size, shape and color of the vessel, the fineness of the material to say nothing of the personal equation all influence the results.

What is needed is a definite procedure by which standards can be duplicated from time to time and by different chemists without variation.

Such a method has been in use in the laboratories of this Bureau since 1901. It involves the use of diatomaceous earth prepared as follows:

"Wash with water to remove soluble salts; dry and ignite to remove organic matter; treat and warm with dilute hydrochloric acid; wash until free from acid and dry thoroughly.

Grind in agate mortar, sifting through 200 mesh sieve and dry in desiccator. (Standard Methods 1905)"

Take a weighed amount of finely ground material, about two grams, suspend in 500 C. C. of distilled water, shaking vigorously from time to time for two or three hours. Suspend 10 (ten) hours, decant supernatent liquid. Dry and weigh residue. The difference equals the amount in SUSPENSION. Dilute to standard and use as stock.

I have found that standards made in this way from different stocks do not differ perceptibly. All material that remains suspended for ten hours appears to be of the same degree of FINENESS.

*Chemist in Charge, Torresdale Laboratory, Philadelphia Bureau of Water.

We add a small amount of a saturated solution of mercuric chloride and make standards as follows:—use quart bottles of a high grade of white glass free from air bubbles. The standards are 0, 0.5, 1, 2, 3, 4, 5, 7, 9, 11, 14, 17, 20, 23 and 26 parts per million silica.

For readings above 26 we use a special nessler jar with a ground glass stopper (may be obtained through A. H. Thomas Co. Phila.)

We seal these standards. The 100cc standards are 26, 32, 38, 44, 50, 65, 80, 95, 120, 150, 180. For turbidities above 180 dilutions are made with clear water.

During 1913 we made over 24,000 tests with these standards. We have standards made in 1907 still in use. These have been checked from time to time and have not been found to change.

We would not recommend using standards for over six months without checking.

This method while it is ideal for the preparation of standards which can always be duplicated involves considerable labor in the preparation of the diatomaceous earth.

The introduction of fuller's earth seems to be a step in the right direction. I believe this was first brought out by Dr. E. C. Levy of Richmond Va., in a paper before the Laboratory Section of the American Public Health Association, although in the report of 1912 he is not given credit for it.

The idea being of course to do away with the tedious grinding and to obtain a standard which resembles more closely the Turbidity of water caused by clay.

Working then with two objects in view, of having a definite weight and a definite degree of fineness (obtained by suspending for a definite period) we have experimented with fullers earth and have prepared standards which check exactly with our standards made with diatomaceous earth.

Our Method follows:

If a 200 mesh sieve is not obtainable take about 20 grams of fullers earth; if a sieve can be readily obtained take about 5 grams of the sifted material (weighing is not necessary). Place in a gallon bottle and add about a quart of distilled water, agitate thoroughly (as above) and suspend for ten hours. Decant and determine the WEIGHT of the material remaining in suspension by filtering 100-200cc. through a weighed Gooch crucible. Dry and weigh.

It will probably be necessary to coagulate the material by the use of a known weight of hydrate of alumina or a solution of alum. In the latter case the water should be alkaline to precipitate the alum.

The increase in weight will equal the weight of the material in suspension plus the weight of the hydrate of alumina.

We know then the degree of fineness as we have suspended for

a definite period and we have a known weight. From this suspension we can make our stock for use in preparing our standards.

I do not know just how long the standards will keep as the period elapsing since their preparation is relatively short compared with our other standards but in any case it is a simple matter to prepare new ones.

SUSPENDED MATTER

It appears to the writer that the Report of 1912 of the Committee on Standard Methods of Water Analysis of the Am. P. H. A. in dismissing the Determination of Suspended Matter with the words:— "This determination is made by obtaining the difference between the total solids in the unfiltered portion of a sample and in a portion from which the suspended matters have been removed", has practically omitted all description of the method.

It is almost impossible to get comparable or even consistent results in this way; moreover the amount of fixed and volatile suspended matter (very important for sewage) is lost entirely.

In the report of 1905 the following note appeared:—"The use of a tared filter of asbestos in a Gooch crucible (50a) may be found advantageous and the suspended matters determined directly."

The note 50a refers to a paper by Thomas and Hall of the Phila. Bureau of Water. Journal Amer. Chem. Soc. 1902, 24 p 538.

Phelps some time later about 1906 under the heading "Gooch Crucible for the Determination of the Total and Volatile Suspended Matter in Sewage" improved on the Thomas and Hall Method in that he used a crucible with a mat of asbestos about 1-16″ in thickness, omitting the stones and perforated thimble recommended by the others.

For water we have been using the modification of Phelps for five years at Torresdale and have obtained very consistent results for both the amount of fixed and volatile as well as the total solids.

For waters containing fine clay we use 250-500 cc. Ordinarily we use 1000 cc. for waters with a turbidity of 50 or less. For fine clay we filter through a filter as prepared by Phelps, after coagulating with 5cc. of an alum solution containing 3 parts per million Al_2O_3.

After standing for 1-2 hrs the alum with practically all the clay has settled out and the sample is ready for filtering.

RESERVOIR WELL FOR THE ROBINSON WATER SUPPLY.

BY CHARLES TRIMBLE.*

Robinson is located in Crawford County eight miles from the Wabash River. When in the year of 1908 its rapid growth demanded a more adequate water supply, we began to look about for a suitable location for a reservoir well, by this I mean a reservoir into which water would enter under its own head. After three test wells were drilled in the vicinity of the Wabash River, a site was chosen and an open well started. This well proved a failure due to the fact that water was found in quick sand which would flow into the well almost as readily as the water. However it was operated in connection with three drilled wells for two years when it was decided to try for a better location. A test well was drilled two miles from the Wabash River. At a depth of eighteen feet water was found in a coarse gravel formation eighty-three feet in thickness. Upon finding such a thickness of water bearing gravel so near the surface, the idea of the reservoir well was abandoned, and four eight inch wells were drilled. These supplied water for one year. During this time a great deal of trouble was caused by the screens sanding up. In the fall of 1911 it was decided to dig a reservoir into this water bearing gravel, this time on a larger scale. After acquiring the necessary machinery, consisting of a boom derrick, hoisting engine, dump and clam shell buckets work was begun. In the former attempt a flat board shoe had been used as a foundation on which to start the brick wall. Difficulty was encountered in the use of this, by its having no sharp edge, therefore making slow progress after reaching water. The idea now occurred to make a shoe with a sharp edge. To do this a form was made twenty-five feet in diameter, sixteen inches wide at the surface, and thirty inches deep tapering to the outer edge at the bottom. This made a circular form with the cross section in the shape of an inverted right angle triangle, around the outer edge of which was placed three sixteenth inch by thirty-six inch (3-16″×36″) boiler plate securely riveted and perforated to permit the use of a staggered row of eye bolts. Through these eyes was passed a ⅝″ messenger wire to make fast to the outer shell and reenforce the concrete that was then

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poured into the form. 14" brick wall layed in cement mortar and plastered outside to keep the water out was started on this shoe. Provision was made for securing anchor rods in this to extend up through the wall for the purpose of holding the shoe and wall together in case the shoe should in a soft formation have a tendency to fall away from the wall. The wall being started, excavation was begun on the inside, the dirt being taken out by the dump bucket. With the excavation from under and the weight of the wall on top the shoe was easily started. The wall was battered ½" to the foot. If more than ½" to the foot is given a cavity will form on the outside allowing the wall to move from an upright position should one side of the shoe strike an obstacle such as a boulder. Care should be taken in starting the shoe evenly for once it begins to settle faster on one side it is almost impossible to straighten it again, as the dirt will have caved in on the side not going down. Upon reaching the water bearing gravel, the dump bucket was abandoned and the clam shell used because the water coming in made it impossible for men to work inside. In the meanwhile the brick were being laid, thereby increasing the weight of the wall as the increasing depth demanded. After excavating ten feet into this gravel it was decided that a sufficient supply could be obtained. No further excavation was deemed necessary. The well was then tested. Water was discharged for two hours through an 8" pipe. After pumping off the head in about twenty minutes, the water could not be lowered. This well has been operated for two and a half years and at no time has there been any indication that the supply was not sufficient. We are now supplying a population of 10,000 including two refineries, forty ton ice plant and drilling wells in the oil fields adjacent to the city of Robinson. A contract has been recently secured to furnish water to another city of 3,000.

PUMPING CITY WATER BY ELECTRICITY.

BY J. M. BRYANT.*

Introduction. In many of the smaller cities of this state water supply systems could be installed if the cost of operation could be brought within the means of the community. Even in many of the larger cities where systems are now in operation there is room for distinct improvement in the operating costs. For the steam driven pumping station the large items in the operation expenses are those for fuel and attendance. Both of these items are either absent or lowered materially in the electrically driven station.

Nearly all of these communities are within easy reach of a transmission system or have one or more electrical plants in their own midst. Power can be produced more easily in one large power plant located at a water power privilege or within easy reach of a coal supply than in several smaller stations to some of which coal may have to be hauled by wagons. The problem of electrifying a pumping plant becomes an analysis of the following items,

1. First cost of the equipment,
2. Cost of operation including power, repairs and labor,
3. Reliability of the equipment.

In this discussion of the question it will be assumed that electric power is available for driving the pumps, and that this may be obtained at a fair rate since the pumping company or the city has recourse to the Public Utilities Commission at any time for an adjustment of rates.

Cost of the Pumping Units. A comparison of the cost for steam and electrically driven pumps of the same capacity reveals the fact that the electric equipment costs from one-fourth to one-half that of the steam driven units. Considering that, for new installations, a saving is also made in the first cost for boilers, buildings, etc., it certainly is fair to assume that the cost of the power plant portion of the water works equipment is reduced to one-fourth that for steam driven stations.

In order to analyze the effect of this reduction on the annual fixed charge the following table is taken from an average of 22 cities in Wisconsin from the reports of the Wisconsin Railway Commission. (7 W. R. C. R. 301; 8 W. R. C. R. 341).

*Asst. Prof. of Elec. Eng., University of Illinois.

AVERAGE COST NEW OF WATER WORKS SYSTEMS IN 22 WISCONSIN CITIES.

		Per cent. of Total Cost New
1.	Land	3.10
2.	Wells, intakes, and suctions,	8.39
3.	Filters, reservoirs, standpipes,	6.28
4.	Distribution system,	63.75
5.	Power plant equipment,	8.86
6.	Buildings and miscellaneous structures	6.37
7.	Office furniture, appliances, tools, etc.	0.80

Adding together items 5 and 6 it may be seen that the total cost in power plant equipment and buildings represents 15.23 per cent. of the total cost new of the equipment. Lowering this to one-fourth of its present value by the use of electrically driven machinery will affect an annual saving in the fixed charge, which may be taken as 15 per cent. of the cost new, by

$$0.1523 \times 0.75 = 0.114,$$

or 11.4 per cent. This will in turn affect the cost of operation by

$$0.15 \times 1.114 = 0.017,$$

or 1.7 per cent. of the present cost of operation of the steam driven station. This means that, for the conditions above assumed, the fixed charges necessary to cover the initial investment are reduced by 1.7 per cent. of that investment, or for the same income, and with other operating expenses constant, an increase in the annual profit of 1.7 per cent. of the investment. Other items in the operation cost will be discussed under the next heading.

Cost of Operation. Items in the annual cost of operation which are less in the motor driven station than for either steam or gasoline driven pumps are the following

1. Interest on the investment on account of lower investment as explained under the last section.

2. Depreciation is less for the centrifugal pump and electric motor. Depreciation in the motor is almost negligible if the motor is properly housed and cared for. The motor may have to be laid aside on account of obsolescence due to improvements in electrical equipment which would secure additional saving in cost of operation at a later date, rather than on account of the wearing out of any of the motor parts.

3. Cost of motor repairs is negligible in comparison with those for a steam or gasoline driven unit on account of the absence of steam and heated gases and of reciprocating parts.

4. Cost of motor attendance may be made very small. If the pumps can be located near the plant which furnishes the power no

attendance need be provided outside of that which the power company is willing to furnish for the privilege of cutting off the demand of the large motors at the time of their station peak loads. For large stations and for isolated plants one attendant can care for a large number of motors and pumps. Nearly all the attention that is required is that necessary to start and stop the motors at the proper time and to stand by in case of fire to connect in enough pumps to supply the necessary volume and pressure.

5. Practically no cost for lubricating oils since the pumps and motors are nearly always self lubricating, using the same oil over many times.

6. Very low maintenance cost compared with a steam or gasoline driven plant. The fires in a steam plant have to be kept banked at times of no load and ready to take on fire pumps if necessary. This item of fuel cost for banked fires forms one of the large items in the annual operation sheet of small plants. Maintenance for the motors and pumps is also a much lower item than for steam and gasoline driven pumps.

Reliability. Reliability in city water pumping is of the utmost importance. In many installations, even in large cities, this factor has been sacrificed in order to lower the first cost of the equipment. There may result from this neglect low pressure in the water mains, and lack of volume for fighting fires causing excessive fire losses and also high insurance rates on real estate for such cities. The electric motor is more reliable than the steam or gasoline engine. In order to increase the reliability of the whole system the following suggestions are given.

1. The motors should be located above all possible flood levels. Although a few cases are known of motor driven mine pumps operating under water and pumping the mine dry, the insulation is not usually guaranteed to stand such treatment.

2. Instead of installing one large motor and pump to furnish the total amount of water for the high pressure service at least two units and preferably three should be installed. When installing three units the combined capacity of any two should be able to supply the peak load of the station. This method of design allows the unit or units in operation to run without throttling and at their full capacity. Throttling a centrifugal pump or running it below speed lowers the efficiency of the equipment and raises the cost of power by requiring a greater number of kilowatt-hours to pump the same amount of water.

When the pumping-station is situated at some distance from the power plant duplicate pole lines should be installed and over routes widely separated. When the wires pass through city streets a fire in a given quarter may destroy one pole line but service may be main-

tained over the other line. Repairs may also be made on either line and at any time without interrupting the operation of the station.

4. Proper lightning protection should be provided at both ends of the transmission line to the pumping-station, to protect all electrical apparatus. The electrolytic arrester has been found to be the most reliable type now in use. Its first cost is slightly higher than that of other forms, but it gives better protection in all cases of lightning or high voltage disturbance from other causes. It operates on the principle of a safety valve, discharging excess electrical pressure from the line and then stopping the discharge at normal pressure, automatically setting itself for the next discharge.

Choice of Motor. The electric motor can be adapted to drive any type of pump. The greatest efficiency of mechanical transmission is of course secured by the least amount of gearing or belting. The centrifugal pump lends itself best for motor drive since it runs most efficiently at the higher speeds. The higher the speed, the lower the cost of the motor and pump. Information in regard to the proper choice of speeds can always be obtained from the pump and motor manufacturers.

The squirrel cage induction motor is a little more simple and reliable than the wound rotor types. It is suitable for starting centrifugal pumps of small capacities without too great a starting current by the addition of a compensator if the pump outlet is closed when starting. The wound rotor motor with slip rings and external resistance is preferable for sizes above 50 horsepower in order to secure the higher starting torque with low line current. Resistance in the primary or line side of the motor for starting should not be used, since the motor then draws from two to five times full load current from the line at the start. This is avoided by the use of the compensator starter or the slip ring motor.

When large pumps are to be driven at a considerable distance from the power plant, transmission line losses may be reduced by the use of one or more synchronous motors in the pumping station. These motors can now be secured with sufficient torque for starting pumps. By the proper use of synchronous motors a large saving may sometimes be made in power consumption.

Cost of Power. Electrical power for pumping should receive the lowest rate of nearly all classes of service furnished by a power plant. With water storage facilities in reservoirs and standpipes capable of taking care of the peaks in the pumping demand and also supplying the water for the two or three hours in the day when the commercial load on the station is the greatest, the power for the pumps may be supplied without any increase in the station maximum demand. The increase in the station output incident to this load will then improve the load factor, lowering the cost of producing

unit power and delivering it to the switchboard. The proper rate to be charged in any community should be properly determined by a competent engineer or by the Public Utilities Commission, and not left to the governing body of the community and the public utility without expert advice. The public utility should be encouraged to seek the pumping load and the city to cooperate in securing a price giving justice to all consumers. This cooperation should extend not only in the matter of securing rates, but also in installing the equipment best for all concerned and in operating it at times when the company can best afford to supply the power. This same rule should also apply to combined municipally owned plants; each part of the service should bear its proper portion of the fixed and variable charges.

CHEMICAL STANDARDS FOR THE HYGIENIC PURITY OF MONTANA WATERS.

BY W. M. COBLEIGH.*

The public water supplies of Montana are taken from a variety of sources. The purpose of this paper is to show the differences in the composition of the waters from these sources. With these data it will be possible to draw conclusions concerning chemical standards of purity suitable to Montana conditions.

In the mountainous portions of the state, as a rule, city water supplies are taken from streams above human habitations. These represent the purest waters found in the state. The average of the analyses of thirteen of these water supplies is tabulated below. These samples were collected during the fall and winter months when the organic content was the lowest.

	Parts per Million.
Solids	99.1
Free Ammonia	.0152
Albuminoid ammonia	.028
Nitrogen as Nitrites	.000
Nitrogen as Nitrates	.102
Chlorine	Absent in all samples.

Shortly after the above results were obtained the writer attempted to use them as a partial guide in passing opinions on the sanitary quality of water supplies taken from the Yellowstone River at various points where there was some reason to suspect that the water was a menace to health. The results of analyses at these points on the river were much higher than could be accounted for by the amount of sewage known to be entering the river. Consequently, samples were then taken from the Yellowstone River above the town of Gardiner and above the mouth of the Gardiner River. This is a point on the Yellowstone River above all sewage contamination and it was expected that the analyses would give results similiar to other mountain streams. That this was not the case is shown by a typical analysis tabulated below.

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	Parts per Million
Solids	150.00
Free Ammonia	.25
Albuminoid Ammonia	.09
Nitrogen as Nitrites	.0045
Nitrogen as Nitrates	.09
Chlorine	11.50
Oxygen Consumed	1.4

This analysis was checked by taking other samples and it was learned that the Yellowstone River at points above sewage contamination contains more free ammonia and nitrites and at times more albuminoid ammonia than it does at the intakes of any of the cities using the water, all of which are located at varying distances below sewage outlets. In this connection it should be stated that the mountain streams flowing into the river below Gardiner contain no nitrites and only a small amount of free ammonia. The dilution, therefore, is a factor in decreasing nitrites and free ammonia.

The results so far point to the conclusion that the river water contains more free ammonia and nitrites during the winter months when most of the water in the river comes from Yellowstone Lake than it does in the spring and summer when the flow is increased by melting snow. The varying character of the water above sewage contamination and the fact that the water normally carries substances usually contributed by sewage makes it very difficult to give to chemical data obtained at city intakes any diagnostic value. While it is evident in this case that the free ammonia and nitrites do not have their origin in sewage, yet the exact source has not been traced so far as the writer knows. It is possible they are developed by chemical action in the geysers and springs of the Yellowstone National Park.

Water of still a different character is found in Northern Montana. The chief sources for city supplies are the Milk and the Missouri Rivers. The waters of these rivers are high in organic matter, which is not derived from city sewage. The organic content increases as the rivers flow to the eastern part of the state where outcrops of lignite coal frequently occur. The effect of the coal is shown in the following analysis of a spring in a sandstone strata which is underlaid with lignite coal. The spring is far from any source of contamination.

	Parts per Million
Solids	1880.0
Free Ammonia	.186
Albuminoid Ammonia	.28
Nitrites	.00
Nitrates	Trace.
Oxygen consumed	6.35
Chlorine	5.1

Water of this character flows into both the Missouri and Milk vers at numerous places. It is evident that the chemical data on aters of this kind cannot be compared with the data reported on the ire mountain streams.

Another source of water for city use in Montana is the deep well. he following is a typical analysis. The well was drilled to a depth 610 feet and is cased. It is located far from any source of conmination.

	Parts per Million
Solids	1008.0
Free Ammonia	.235
Albuminoid ammonia	.037
Nitrogen as Nitrite	.008
Nitrogen as Nitrate	Trace.
Oxygen consumed	1.25
Chlorine	10.70

It is evident that there is a great variation in the organic content f the surface waters in Montana, known to be free from sewage ontamination. This variation is so great that it is impossible to use universal chemical standard of purity for all waters of the state. Iowever, it has been possible by carefully studying the qualities of the aters from various sources to adopt local standards of purity, which re very necessary to use in connection with bacteriological data.

HYPOCHLORITE TREATMENT NOW FIRMLY ESTABLISHED.

BY C. A. JENNINGS.*

There can be no question now about the efficacy of hypochlorite treatment of public water supplies. Its adoption has spread very rapidly since its introduction at the Bubbly Creek filter plant in Chicago in 1908. The writer believes that there are at least 600 cities in this country now using this method of disinfecting their water supply. Wherever a proper survey was made and it was decided by capable authorities that hypochlorite treatment was needed and the chemical was properly applied thereafter, good results have followed. The writer knows of no city following this procedure, that has found it necessary to discontinue the use of the treatment. It is true that in some cities, hypochlorite treatment has come into bad repute with the water consumers because of a taste in the treated water at times. In the experience of the writer, such cases are always due either to a poorly designed plant, improper application, expecting a removal of bacteria beyond what was practical or to the fact that hypochlorite treatment was not adapted to remedy the particular water troubles.

Hypochlorite has its own sphere of usefulness and beyond that it is practically useless. It is to be used primarily to eliminate from a water supply the disease producing organisms of intestinal origin, such as typhoid fever, para-typhoid, dysentery, etc. The efficiency of the treatment will vary inversely with the turbidity of the water. Hypochlorite is now used in conjunction with rapid sand filters, slow sand filters, coagulation and sedimentation, plain sedimentation, impounding reservoirs, and alone.

With the layman of today so widely awakened to matters pertaining to health, more and more thought is being given by him to the purity of his drinking water. He is beginning to realize that the physical properties of a water do not necessarily indicate the health giving properties.

It is acknowledged that hypochlorite treatment is not a substitute for filtration; but there are some impure water supplies which because of their physical condition do not need filtration. Within

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the past two months Mr. Rudolph Hering of New York, reporting on the Buffalo water supply said: "It is my opinion that sterilization by either method (hypochlorite of lime or liquid chlorine gas), will safeguard the public health at a very much lower cost than the adoption of filtration at this time. As soon as the city is prepared to pay the cost of giving the water at all times an excellent appearance, filtration is the system to be adopted." It is often a question whether the results accomplished by filtration of a given water supply, are worth the expenditure, provided of course, that the water as furnished the consumers is free from pathogenic organisms. Many lake cities are situated similarly to Buffalo as regards water supply. Erie, Penn., and Evanston, Ill., are now completing the installation of rapid sand filters. Cleveland, O., has broken ground for the first of two filtration plants. Filtration has been recommended for the water supply of Chicago. All of these cities have been using hypochlorite treatment for two years or more, producing a water that is bacteriologically safe and each city has reduced its typhoid fever death rate very appreciably.

Hypochlorite treatment is now firmly established because it has accomplished what its conservative advocates originally claimed for it. Its selective action for the germs of water borne diseases has been proven by bacteriological analyses over a period of almost six years and by typhoid fever statistics during the same period. The writer has collected typhoid fever death rates from a number of cities and selected a few as being representative. The water supplies used include lake water with only hypochlorite, very turbid river water with coagulation, sedimentation and disinfection, impounding reservoirs with hypochlorite, plain sedimentation and hypochlorite and rapid sand filtration with disinfection. The statistics cover a maximum period of eleven years previous to disinfection and five years following its introduction. Obviously the latter figure is limited because hypochlorite was not introduced until 1908. The death rates mentioned are expressed as annual death rates per 100,000 of population.

For eleven years previous to the use of hypochlorite, Baltimore had a typhoid fever death rate of 35.2. Eliminating the year of 1911, during the last six months of which hypochlorite was used, the death rate was reduced to an average of 22.8 for the years of 1912 and 1913 while using hypochlorite, a reduction of 35 per cent. (See Fig. 1.) Baltimore uses chemical coagulation and sedimentation and hypochlorite. A rapid sand filter plant is being installed at this time.

The average typhoid death rate in Cleveland, O., for the eleven years previous to the introduction of hypochlorite in Sept. 1911, was 35.5. The average for 1912 and 1913 while using hypochlorite,

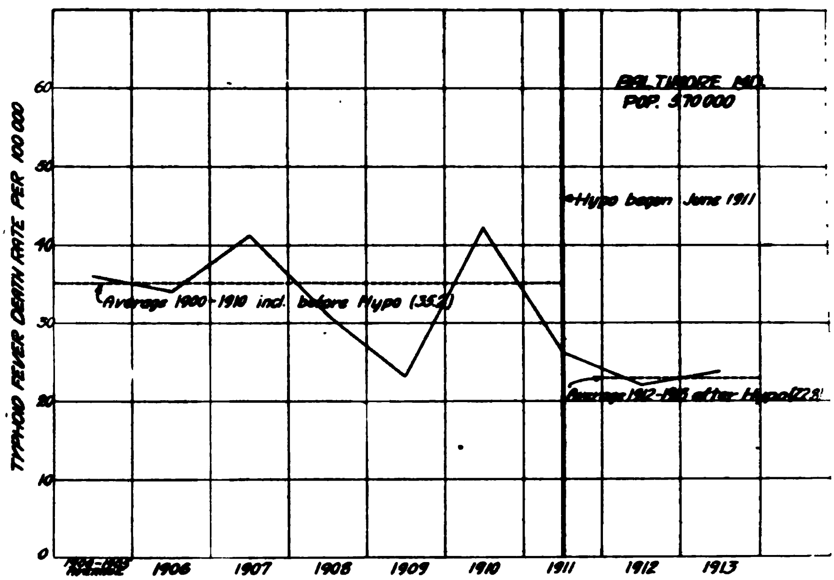

Fig. 1. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Baltimore, Md.

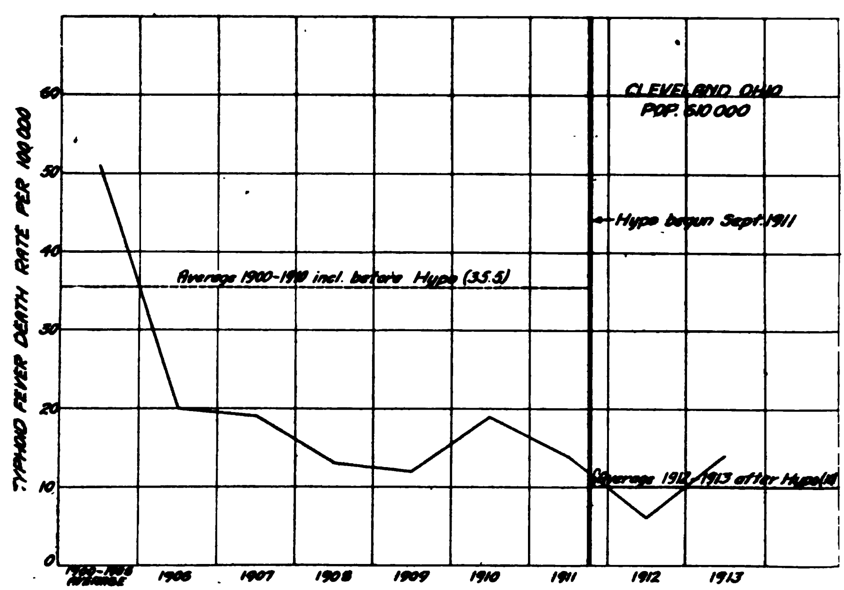

Fig. 2. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Cleveland, O.

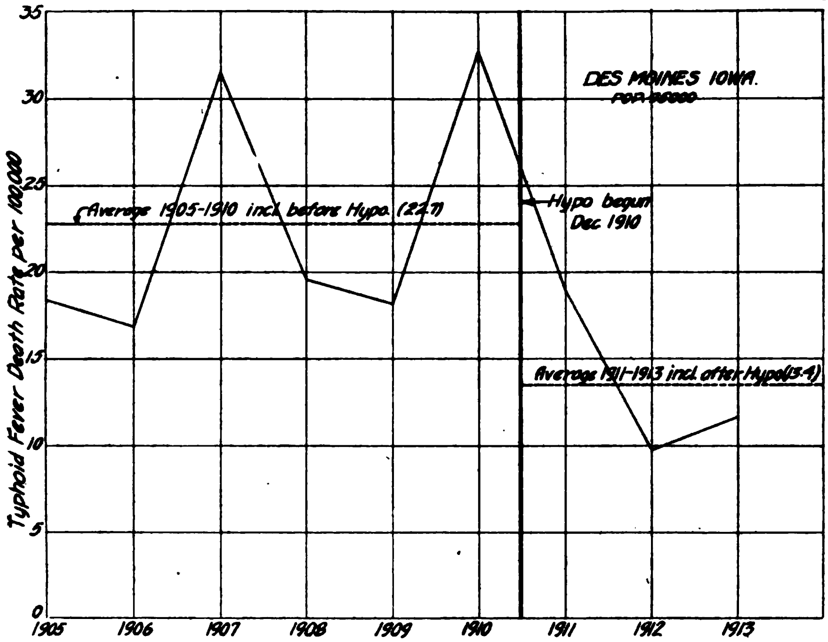

Fig. 3. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Des Moines, Ia.

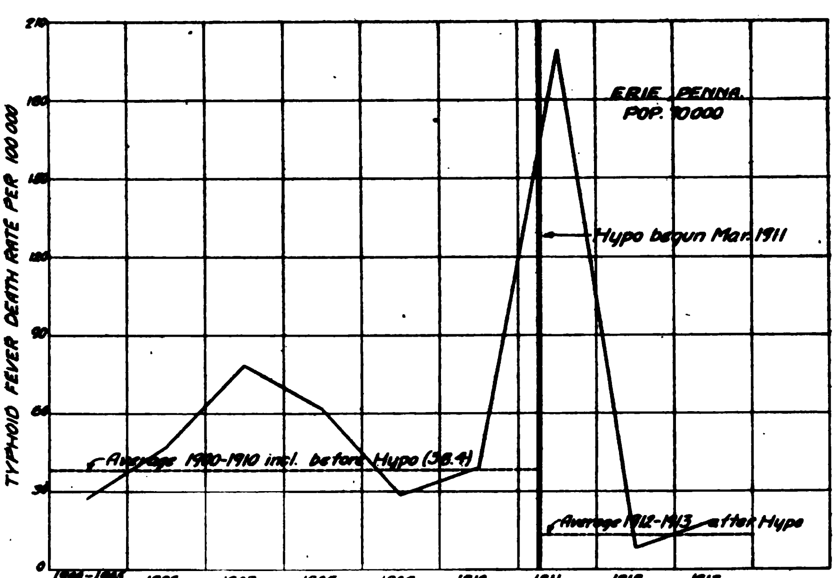

Fig. 4. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Erie, Pa.

was 10, a reduction of 72 per cent. (See Fig. 2.) Cleveland uses no other treatment than disinfectant at this time.

At Des Moines, Ia., the water supply is collected in filter galleries under the old bed of the river. Hypochlorite treatment was begun in Dec. 1910 during a typhoid epidemic. The average typhoid death rate for the years 1905-1910 inclusive was 22.7 and for the three years while using this process, it was 13.4 per 100,000, a reduction of 41 per cent. (See Fig. 3.)

During the winter of 1910-1911, Erie, Pa., experienced a typhoid epidemic of a very severe form. The death rate from this disease was 197 per 100,000 for the year 1911. Hypochlorite treatment was begun in March 1911. The average typhoid death rate for the eleven years, 1900-1910 inclusive, was 38.4 and for 1912 and 1913 while treating the water supply, it averaged 13.5, a reduction of 65 per cent. (See Fig 4.)

Evanston, Ill., is another city on the Great Lakes that suffered a typhoid fever epidemic in 1911, but it was prevented from assuming large proportions by the introduction of hypochlorite in Dec. 1911. An average typhoid death rate of 26 per 100,000 for the years 1907-1911 inclusive, dropped to 14.5 as the average for 1912 and 1913, a reduction of 44 per cent. (See Fig. 5.)

Jersey City, N. J., was the first city to adopt hypochlorite treatment for a municipal water supply, in Sept. 1908. The water is stored in an impounding reservoir and then treated with hypochlorite. The average typhoid death rate for the years 1900-1907 inclusive was 18.7 per 100,000. The average death rate since the introduction of hypochlorite, for the years 1909-1913 inclusive is 9.34 which is a reduction of 50 per cent. (See Fig. 6.)

Kansas City had a typhoid death rate of 43 per 100,000 during 1910. Hypochlorite treatment was begun in Jan. 1911. The average typhoid death rate for the years 1900-1910 inclusive was 42.5 per 100,000. During 1911, 1912 and 1913 the average was only 20. This was a reduction of 53 per cent. over the former rate. (See Fig 7.)

The water supply of Omaha, Nebr., has been coagulated and settled in basins and then treated with hypochlorite since May 1910, when disinfection was installed because of the large amount of typhoid fever in the city at that time. The typhoid death rate in 1910 was 89 per 100,000. The average typhoid fever death rate for 1900-1909 inclusive was 22.5. For the years 1911, 1912 and 1913, the death rate averaged 11.8, a reduction of 47 per cent. (See Fig. 8.)

Summarizing, it is seen that in each city a substantial reduction in typhoid fever was effected following the introduction of hypochlorite. These reductions have been consistent. For the eight cities, the maximum reduction was 72 per cent. (Cleveland), and the minimum was 35 per cent. (Baltimore). The average percentage reduc-

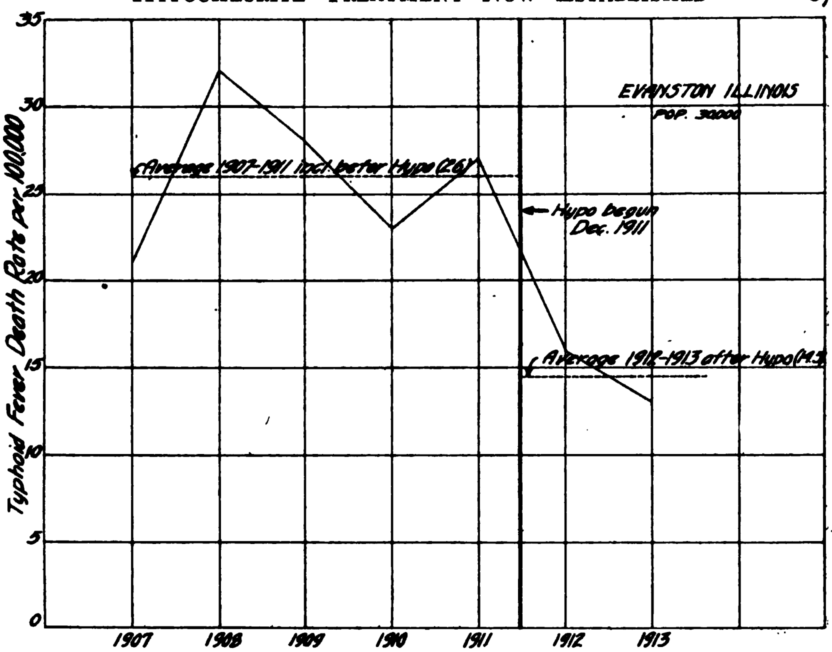

Fig. 5. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Evanston, Ill.

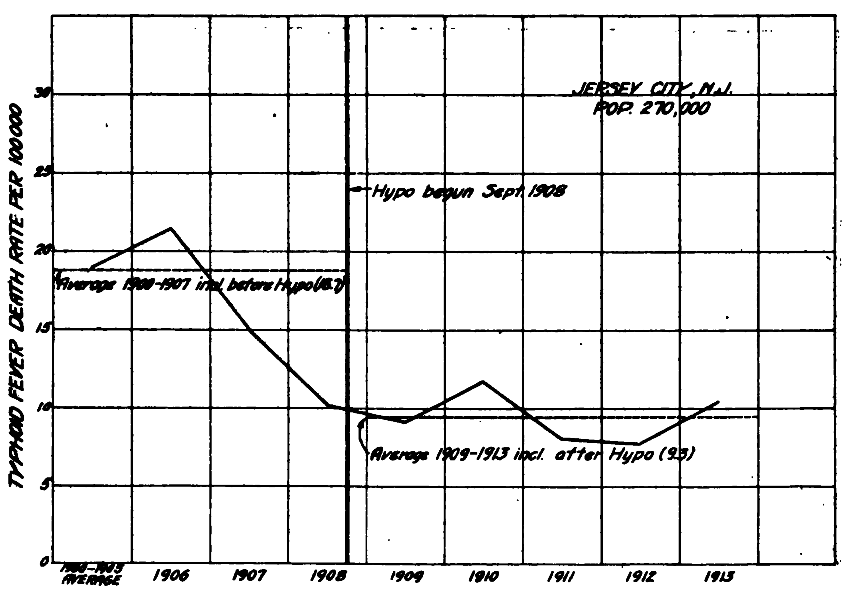

Fig. 6. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Jersey City, N. J.

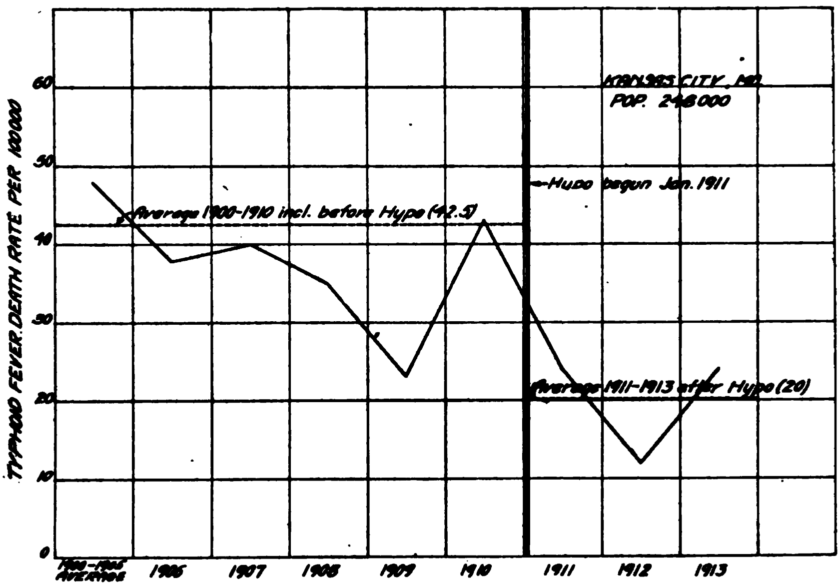

Fig. 7. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Kansas City, Mo.

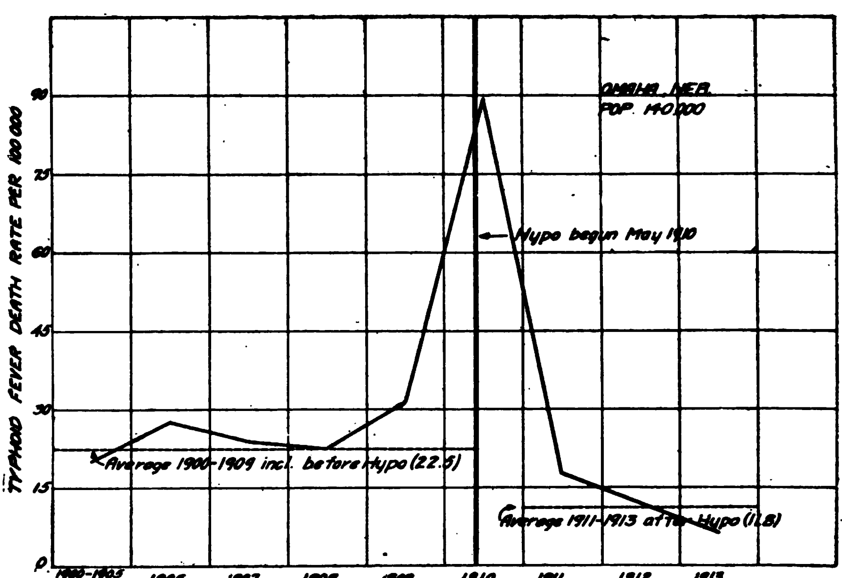

Fig. 8. Typhoid Fever before and after Introduction of Hypochlorite Treatment at Omaha, Neb.

tion was 51, which is very satisfactory. The total population of the eight cities is 2,033,000. With an average reduction of 15.8 deaths per 100,000 population for each year and with a value of $5,000 for each life saved, the saving to these cities amounts to $1,606,000 per year. Certainly hypochlorite treatment has proved a blessing.

Formerly it was thought that the water supply of any city with a typhoid fever death rate of 20 or less per 100,000, was above suspicion. This view has changed recently. Of the eight cities named, only one had a typhoid death rate of less than 20 previous to the use of hypochlorite (Jersey City with 18.7). The average was 30.2. The average since disinfection was begun, is 14.4 and only one city (Baltimore with 22.8) has a rate above 20 per 100,000.

It is to be noted in conclusion, that of the eight cities, six showed a higher typhoid death rate in 1913 than in 1912. It has been said that 1913 was a typhoid year. During 1910 and 1911 there were many typhoid epidemics. What the death rates in these cities would have been if hypochlorite had not been in use will never be known. However, it is safe to say that hundreds of lives were saved during 1913 that would otherwise have been sacrificed to that preventable disease, typhoid fever, had not the water supplies been disinfected with hypochlorite.

WATER TREATMENT FOR RAILROADS.

BY R. C. BARDWELL.*

I will forego the usual preliminary of the water treatment paper, and in this article presume that all present are duly familiar with the fact of how the gentle rain from heaven absorbs the various mineral impurities in its course upon the earth beneath. Needless to say they are present in varying amounts in all waters available for consumption, and cause numerous troubles in the manufacture of steam power through the formation of scale in the boilers or through foaming because of the alkali water carried over into the steam heads.

Those of you who are not directly connected with the operation of steam plants have witnessed this phenomena of scale formation in the common household kettle, and exercising imagination may be able fo conceive of the considerable amount which is similiarly formed in the large locomotives of 2500 square feet of heating surface and evaporating over 5000 gallons of water per hour. This scale formation greatly lessens the life of the boiler and appurtenances, necessitates frequent costly repairs, and delays traffic. In the case of the household kettle after the worthy husbandman has wearied of his efforts in scraping out the persistent scale or has punched a hole through the bottom during the course of the proceeding, it can be turned over to the ashman and its successor procured for a very nominal sum. In the case of the locomotive the "nominal" sum is around $20,000.00, so that it is obviously to the advantage of those concerned to prolong the life and service by every economical means, and to reduce as far as possible the cost of repairs and loss of time.

The scientific investigation of this economy is of comparative recent development, that is, it has been worked out principally in the past fifteen years. It is no longer an experiment, although like many innovations it is still regarded in a few places with suspicion. Although originating in England, if the report of the International Railway Congress of 1910 at Berne can be taken as a criterion, the United States leads the world in water softening efficiency.

On the generally softer waters of the Eastern part of the country the process was first tried with most gratifying results. On the harder and heavy scale waters of the middle West and Western districts

*Chemist, Missouri Pacific Railroad.

it is now regarded as a practical necessity. In cases where it has been successfully installed and competently operated the increase in the life of flues has amounted to from 75 per cent. to 150 per cent.

The report of the committee on Water Service for the 1914 convention of the American Railway Engineering Association shows that on six representative trunk lines through the middle West there are now in service 237 complete treatment plants and 111 soda ash partial treatment stations, ranging from 5 complete plants on one road to a maximum of 112 on another, and from no soda ash plants on several to 86 on one. Several railroads arrange for placing soda ash directly into the engine tanks at the terminals. This is conducive to foaming conditions, but the economy derived from the scale removal more than justifies the foaming complaints.

On the road with which I am connected there are at present 45 complete water softening plants in operation, the majority being on the hard waters West of the Missouri River. The average amount of water treated per year, reducing the hardness so that it will form practically no scale, is 1,692,000,000 gallons. The total average amount of scale removed from this water is 5,537,000 pounds, which would make over 110 carloads at 50,000 pounds each. A considerable amount when it is remembered that but for treatment this scale would have to go through the engine boilers and most of it be removed by taking out the flues. The total annual cost for the above treatment including chemicals, additional supervision necessary, maintenance, interest and depreciation on plants is about $65,000.00. However conservative figures show that with this expenditure there is a net saving of about $105,000.00, from cutting down the following losses:

1.—Frequent renewal of flues and other parts of boiler on account of scale accumulation and injury to flue ends from repeated caulking.
2.—Labor and caulking flues and other engine house boiler repairs.
3.—Loss of engine time during boiler and firebox repairs.
4.—Loss of fuel due to the insulating effect of the scale on the flues and other heating surfaces.

Besides these are the indeterminate benefits in the road performance of locomotives by reducing the failures and interruptions to traffic with the reduction of the number of locomotives required for a given traffic.

At one terminal approximately 18,000,000 gallons of water are treated monthly, eliminating 5 pounds of scale per 1000 gallons or a total of about 80,000 pounds per month. The cost for chemicals for this is about 4 cents per 1000 gallons or a total monthly bill of about $720.00. The length of life of flues using the straight raw water before the installation of the softening plants was from 8 to 12

months with serious trouble on account of frequent leaks. The locomotives now using the straight treated water average 18 months between shoppings and the trouble with leaky flues is practically eliminated.

At another terminal about 30,000,000 gallons of water are treated monthly, removing 3 pounds of scale per 1000 gallons or a total of about 90,000 pounds. Prior to the installation of the softener, five boilermakers, days, and four boilermakers, nights, were employed caulking flues. After treating plant was put in operation this was reduced to one man, days, and one man, nights. The saving in this one item alone is $5712.00 per year on an $8000.00 investment. The life of the flues has increased from 8 to 12 months.

In most cases where softening plants are installed the foaming conditions are increased, especially for the first few days after the treatment is started, due to the fact that the old scale in the boilers is loosened and, falling off, increases the amount of suspended matter in the water, making a dirty boiler which seems to be the most important of the contributary causes of foaming.

To soften a water to three grains per gallon or less of incrusting salts, which is the object in most cases, demands a purity in this respect of 3 parts in 58,341 or 99.995 per cent. This merely shows the deceptiveness of reporting water softening on the percentage basis, for although sounding complex, it is a comparatively simple matter. However each individual water has its peculiarities such as temperature at different seasons and the difference in content of magnesium salts which slow up the reaction and without due allowance for same leave a milky water as a final product. Creek waters of course change with the precipitation and I have also found that in some parts of the country well waters become softer in winter while others get harder.

So far the development of water softening on a large scale has centered around lime and soda ash as the chemicals which produce the results for the least cost. However, barium hydrate is the ideal reagent on account of its leaving no detrimental byproducts as in the case of soda ash. So far the expense has retarded its development. Numerous boiler compounds, through the high degree of exploitation given, have been tried by a few railroads but investigation would show that even where the work desired was done the cost greatly exceeds that of the recognized methods. Inert powdered graphite is now being largely exploited as a cure-all for scale troubles, but its economical merits are yet to be proved. The "sunlight on corrugated aluminum" a patented process, which was supposed to render the scaling material inert in the water without removing it chemically has been tried at several points in this section and seems to have proven unworthy. The Permutit water softener, the artificial zeolite, discussed

by Mr. J. F. Garrett at our last meeting has the objection in railroad work of replacing the incrusting carbonates with sodium carbonate, that is, waters which are sufficiently hard to warrant the expense of treatment as a rule contain sufficient incrusting carbonates, which if replaced by sodium carbonate could not be used on account of foaming properties. Therefore it would seem that common lime and soda ash will continue to remain in service.

DISCUSSION.

Hueninh: How much time is necessary for the reaction to take place?

Bardwell: The time for reaction depends on the temperature of the water, content of magnesium salts, and the thoroughness of the mixing given the chemicals and the water. In the intermittent system we figure on 30 minutes thorough agitation with air and then two hours for the sludge to settle and give a good clear water. In a continuous system where the upward flow of the water hinders the settling it is advisable to allow four hours flow between the place where the chemicals are mixed with the water and the place where the treated water is drawn over into the storage tank. In all cases a slight overtreatment with lime will push the reaction to completeness and hence shorten the time.

Pownall: Have you made any tests to determine the amount of alkali salts in the boiler which will cause foaming when no anti-foaming compound is present?

Bardwell: We have made a few tests. Without the use of anti-foaming compound the concentration can be run up to about 180 grains per gallon in passenger locomotives and to about 200 grains per gallon in freight locomotives. If the foaming salts contain a high percentage of common salt the allowable concentration is lowered from 10 to 30 grains per gallon. With the use of an anti-foaming compound which we manufacture at Kansas City, 293 grains per gallon is the highest concentration we have found in a passenger locomotive. In a recent test with a 105 ton freight engine the concentration was run up to about 350 grains per gallon without trouble from foaming though full tonnage was handled.

Ely: What is your opinion of graphite. We have been using it instead of a boiler compound and find it very successful for stationary boilers.

Bardwell: Powdered graphite has been recognized for some time as beneficial for loosening scale. Recently it has gained prominence through extensive exploitation and advertisement by several large graphite companies. It will unquestionably soften the hard scale but common mud will sometimes do that, and as far as its actual merits are concerned there is still considerable controversy. As far as

economy is concerned the general advice is to use 3 ounces per 1000 gallons, making the cost for treatment about 2 cents per 1000 gallons. The only experience I have had with graphite has been in stationary boilers at Falls City, Neb., the boiler water containing 18 grains per gallon of total hardness, of which about 8 grains were sulphate hardness, formed a very hard scale. With the use of powdered graphite a scale of about the same thickness formed but it was soft and the time taken to clean the boilers was reduced from 3 days to one-half day. I do not, however, like to draw general conclusions from this one case.

Pownall: Mr. Bardwell has brought out the foaming troubles caused by the use of soda ash. The barium hydrate process mentioned is rather expensive at present. Barium carbonate is used in Germany. I do not know of any being used in this country to the present time. The University of Illinois could do a good work by investigating the barium carbonate process. The railroads are so poor that they have to rely on some one else to do such work.

RATES AND THEIR RELATION TO METERS.

BY F. E. HERDMAN.*

Public utility rates of the past and many of those of the present will not stand analysis and the only explanation for their existence is either selfishness or ignorance or both, certainly not the *public good* of the community served.

The flat rate—one of the most vicious of human conceptions, encourages the unprincipled to waste just because they do not pay for that waste, and whom does it benefit—those who want an abundance but do not wish to stand the cost of it; and who pays this cost—those who use economically and are watchful to prevent waste. To be sure all pay to a certain extent (though they do not realize it) but the burden is on the careful ones, the small consumers who are entitled to better treatment.

Most privately operated public utility properties have broken away from the flat rate, not being able to withstand the waste which it encourages, but municipally operated public utility properties (mostly water) are slower in abandoning the flat rate—though I cannot conceive why. Such arguments as I have heard for its continuance are not what you would classify as sound.

The meter is a great advance toward intelligent and equitable rates as it registers against each consumer his consumption. If he is wasteful, he is the one who suffers, if he is economical, he is the one who gains. The consumer pays for what he gets and he can have all he chooses to pay for.

But the meter does not cure all the inconsistencies of rates.

The cost of the *metered* water is:

General expenses & fixed charges.
Operating expenses & maintenance of pumping system.
Maintenance of the distributing system.
Depreciation.

From these is obtained the cost per 1000 gallons.

Generally, rates are on a sliding scale, high for small consumptions and low for large consumptions, one often being several times as large as the the other and with no restriction as to the *character of consumption*. The cost of every 1000 gallons of such service is the *same* and

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unless the factor of profits is of the same ratio to the cost per 1000 gallons as the high and low rates, the large consumer is paying less than *actual* cost and the small consumer is making up the difference, neither from the stand-point of profit would it be equitable for the small consumer to pay all the profits.

Considering a consumer of 10,000 gallons per day and ten consumers of 1000 gallons each a day; for the same service the ten 1000 gallons to the one consumer and the ten 1000 gallons to the ten consumers, cost practically the same to deliver with exception of the clerical work and that is too small a fraction per 1000 gallons to make a change in rate. If these ten consumers combined there would be no question.

Now I will show you where any one of these ten small consumers might be entitled to more consideration than the large consumer. If his consumption were a small steady stream, the demand on the main and on the pumping system would be far less, proportionately, than that of the large consumer with the usual intermittent use. You may say that the large consumer would be of this character of consumption rather than the small. That depends *entirely* on what is supplied; if two residences of the same size—yes, a small *home* and a *mansion*—no. In fact I have seen the maximum demand of one large consumer far more objectionable than that of the number of small consumers to make up the same consumption, all being of the same class of service.

We all recognize that a pumping plant with a certain pumpage can often take on *additional* pumpage, at the cost of even less than cost, for the sake of distributing its cost over a greater pumpage, but while this is shrewd business, it will not stand the analysis of to-day for fair and equitable rates to the consumer.

I believe this is the reason for many of the large *consumption* scheduled rates as analysis of costs cannot sustain their equitability.

Now as to the size of meter—a consumer cannot be allowed to dictate the size of meter though the water property should permit adequate size for the service if it is able to handle that service. It is a loss to permit a larger size of meter than necessary, due to the efficiency of the meter and the cost of the same. As to the proper size for domestic service, I know of no dependable rule—there being such variety of conditions to affect it, even the requirement of different families being a material factor.

The size of the meter is and should be a guage as to the maximum demand of that service; and the minimum charge—which might be designated a "ready to service" charge—should be in proportion to the size of meter. In fact, somewhat proportionately larger as the size of meter increases, judged according to the capacity of the system.

As to the rate per 1000 gallons—In an entirely residence district,

the conditions of service are practically the same, therefore the cost per metered 1000 gallons is the same, the demand on the mains and pumping system is the same. Such being the case there should be only one rate per 1000 gallons.

With commercial interests using water, a somewhat different condition often arises; that is, a continous consumption throughout the day where there is no maximum demand requiring greater capacity of mains and pumps as is the case of the usual domestic consumption. Such consumption is entitled to rates on the basis of the lesser investment in pumping and distributing system required for such service.

If there are consumers using water only at times when the pumps and mains are not otherwise taxed or through independent mains, such restricted use would allow of further legitimate concessions in rates, but rates made to one or more consumers no matter how large, on the basis that expenses and profits are already cared for and these additional consumers will be a benefit at a much reduced rate, because they increase the pumpage and therefore lesson the fixed charges per 1000 gallons, while shrewd business, will not meet the requirements of the day, that the patrons of a public utility company are entitled to—*fair rates.* It would seem fairer to say that the new consumers should pay the full rates for awhile and the old ones have the reduced rates as a relief from past experiences.

The cost of puting the water in the mains is the first factor of cost. If this pumpage can be increased so as to reduce this cost and to such an extent as to warrant a reduction in rates then *all* are entitled to that reduction, not a few. The same is true of the other factors of cost, distribution and general and fixed charges.

To Sum Up:

Flat rates are vicious and obsolute and to-day there can be no excuse for their existence. e

The meter affords an opportunity for intelligent and equitable rates.

A sliding scale of rates on the basis of consumption is neither an equitable or an intelligent basis for rates.

Because the demand of a large consumer on the mains and pumping plant may be, and probably is, in the same proportion as that of the smaller consumer, and therefore each 1000 gallons delivered under that large consumption is of the same cost as each 1000 gallons delivered under the smaller consumption and therefore subject to the same rates.

Because every 1000 gallons delivered by the pumps and passing through the distributing system during the period of maximum demand is of the same cost whether consumed by a large or small consumer, and therefore subject to the maximum rate.

Because the object sought is to increase consumption to the maximum capacity of the plant while an increase of consumption under the sliding scale may, and without question a large proportion of it will, increase the maximum demand in proportion and therefore defeat the desired object and to that extent produce unfair rates as it creates two prices for the same service.

Because small consumers can and do, do as much towards checking their maximum demand as large consumers and by so doing are entitled to the same proportional benefits as large consumers.

The correct system of rates is that all consumption during the maximum demand on the mains and pumping plant shall be charged for at the maximum rate. That all additional consumption shall be charged for at lesser rate or rates based on the smaller investment required for such service. As *all* would have the same opportunity for advantage under this lesser rate it could fairly be figured on a closer margin if judgment so dictated.

Any special conditions of very large supply direct from the pumping plant may produce special rates: but like factors of cost must be considered in like manner for such rates.

To place this in practical form:

The size of meter used should be in accordance with the maximum demand of the consumer and therefore its area approximately measures his maximum demand and we have for the different sizes of meters the maximum demands as follows:

⅝ inch meter	1
¾ inch meter	1.44
1 inch meter	2.56
1½ inch meter	5.76
2 inch meter	10.24
3 inch meter	23.04
4 inch meter	40.96

Taking X as the total consumption in cubic feet under the maximum rates for a ⅝ inch meter, we have the consumption to be charged for at the maximum rate for the different sizes of meters as follows:

⅝ inch meter	1 x
¾ inch meter	1.44 x
1 inch meter	2.56 x
1½ inch meter	5.76 x
2 inch meter	10.34 x
3 inch meter	23.04 x
4 inch meter	40.96 x

The consumption beyond this would be under the lesser rate.

The value of X should be the maximum *domestic* consumption supplied by a ⅝ inch meter.

The minimum or what can be considered *the ready to serve charge* should also be in proportion to the maximum demand measured by the area of the meter. This charge is essential.

This I believe treats all with equal fairness charging all alike for that portion which taxes the maximum capacity of mains and pumps; and a lesser amount for all beyond that amount, thereby giving full credit to the consumers of large consumption and proportionately small maximum demand.

THE PROPOSED NORTH SHORE SANITARY DISTRICT.

BY DAVID H. JACKSON.*

There is a stretch of country lying along the west shore of Lake Michigan, extending from Evanston to the State line which is commonly known as the North Shore. It is for the most part heavily wooded, is high above the Lake and seems particularly adapted for residence purposes. The people of Chicago have recognized its beauties and its many other attractions and during the past twenty years have been moving there in ever increasing numbers so that today there is a solid city from Chicago to Lake Bluff, extending back on an average of two miles from the Lake Shore.

In this stretch of territory are located the municipalities of Evanston, Wilmette, Kenilworth, Winnetka, Hubbard Woods, Glencoe, Highland Park, Highwood, Lake Forest and Lake Bluff and the Government Reservation at Fort Sheridan, while a mile or two north of Lake Bluff comes North Chicago with its rapidly growing industries and immediately adjoining it Waukegan with a population of twenty thousand people. These towns all lie almost entirely on the narrow watershed which drains into Lake Michigan and have always poured their refuse and sewage into that body of water from which in turn they and their neighbors have been drawing their water supply. Indeed until recently all of such sewage was run into the Lake in its raw untreated form and while the territory involved has never, from a sanitary point of view, reached as low a level as some other places near Chicago, yet it is building up with such tremendous rapidity that in a short time the sanitary conditions will be deplorable unless definite action is taken to change the policy now pursued.

Ever since 1908 some of the further sighted residents in this territory have been making efforts to bring about a change in policy and to that end have spent much time and a great deal of money on the work, as your secretary, Dr. Bartow, can testify. That part of the territory under discussion lying inside of Cook county, including the municipalities of Evanston, Wilmette, Kenilworth, Winnetka, Hubbard Woods and Glencoe, is part of the Chicago Sanitary District and will soon cease polluting the Lake though no actual relief has been given up to this time. However, there still remains to be

*Attorney for the North Shore Sanitary Association.

provided for, the territory extending from the Cook county line to the north boundary of Waukegan, and eventually to the State line; but as no sewer systems dumping into Lake Michigan exist north of Waukegan it is not imperative that anything be done north of that city immediately. From and including Waukegan, south to Cook county, conditions are rapidly becoming a menace to the health of the residents in that territory and indirectly to the health of the citizens of Cook county. In 1890 the population of this strip of territory, roughly speaking, was nine thousand. In 1900 it was almost 16,000 and in 1910 it was 30,000 and by 1920 it will undoubtedly be not less than 45,000. As I said before ever since 1908 certain people have been working on the problem but much of their work has consisted in accumulating facts and promoting a campaign of education. For instance during a period of five weeks or more samples of water were taken from fixed points in Lake Michigan every day that the weather would permit and the samples were analyzed by the chemists in the laboratory of the Chicago Health Department and the results carefully tabulated. The work was done under the direction of Dr. Bartow, Dr. F. O. Tonney and Mr. Langdon Pearse and inasmuch as samples were taken from Evanston to Waukegan daily, when the weather permitted, at about sixty points extending four miles into the Lake, a fairly accurate conclusion could be arrived at as to the condition of the water along the North Shore. The results of this survey together with articles by Mr. Pearse, Dr. Evans and Dr. Bartow were then published in pamphlet form and between eight and nine thousand copies distributed. Many meetings were also held and as a result of all these activities a bill was introduced in the Legislature and passed which grants permission to organize a sanitary district in Lake county. Now, pursuant to that law, steps are being taken to organize such a district. The proposed sanitary district will be named the North Shore Sanitary District and will include all of the municipalities I have named in Lake county and generally speaking will include the Lake Michigan watershed in Lake county as far north as the north limits of Waukegan. Before the district can become a fact the question must be voted on and this will be done at the election to be held on April the seventh next, so that now we are busily engaged in educating the citizens to the importance of a favorable vote. As usual there are factions who oppose the district and there is, of course, the common disinclination of tax payers to take on a heavier burden, and finally there is the biggest obstacle of all, the natural inertia of the voters and their reluctance to take a positive stand on such questions.

At any rate as a result of the work already done the public generally recognizes the fact that sooner or later the present method of disposing of sewage must be abandoned and most of them are be-

ginning to believe that before long the Federal Government will step in and put a stop to dumping the sewage into Lake Michigan.

You gentlemen being practical engineers and experts know that to work out the solution of such a problem as confronts the North Shore will require considerable time. But the time which will be required in developing plans is a small part of the time that will be required before those plans can be put into operation. If the people up there delay they will find themselves one of these days in a position where they will be compelled to act hurriedly and it scarcely seems necessary before a body of men like this to point out that work of this kind done in haste is likely to be poorly done and unsatisfactory.

Men who have had considerable to do with public bodies, I think, all recognize the fact that a city or village of medium size does rather poorly the things which are not attracting the public attention. There are so many demands on cities nowadays to take up all sorts of work and to spend money on all kinds of things, that as a result any ordinary unattractive thing like sewage disposal is likely to be neglected. Then also such matters can be handled on a large scale much more ecomically than on a small scale and are much more likely to be efficiently done.

There are today six septic tanks in the territory under consideration, three being in Highland Park, one, the oldest, in Lake Forest, and one each in North Chicago and the Naval Training Station at North Chicago. None of these has contact beds I believe, except the old one at Lake Forest and that whole plant is outgrown and dilapidated. Highland Park probably has done the best work on sewage disposal but now that town is not taking the interest it formerly did. The most enthusiastic worker there died a couple of years ago and already, I am informed, the efficiency of the plants is falling off. However, the health authorities and many citizens are demanding that if a district be not organized, that more disposal plants of some kind be constructed. The result of this will be that more public money will be invested in plants which will always be unsatisfactory under municipal control and are bound to be discarded in a few years at most.

If the situation is to be permanently relieved in the near future and if the public money is not to be spent in temporary makeshifts it would seem the part of wisdom for the voters at this time to act favorably on the matter.

And now, if you gentlemen believe as I do, you can help us in this work by giving us an expression of your opinion in the form of a resolution which can be presented to the voters to let them see how experts look upon the subject.

There is no plan of work adopted yet and none can be until an organization has been created which has power to act and that is the

reason why we are anxious to effect such an organization at the earliest possible date. We can, however, say that in general there are three plans which might be adopted. First, divert the sewage from the lake into the Wilmette Channel of the Chicago Sanitary District, second, treat the sewage partially and run the effluent into the Lake and, third, remove the solids entirely and purify the effluent in some way and then run it into the Lake. In a paper of this length however, I cannot do more than mention these plans and anyway it would be unseemly for me, a lawyer, to discuss such a technical subject.

DISCUSSION.

A committee was appointed to frame a resolution. Later in the session they presented the following resolution, which was adopted.

Resolved, that the Illinois Water Supply Association endorse the formation of a North Shore Sanitary District in Lake county, as a means of attaining concerted and efficient action in solving the sewage disposal problem of the district.

W. J. ALLEN,
A. N. TALBOT,
W. LEE LEWIS,
Committee.

REMOVING GAS FROM WATER USED FOR DRINKING PURPOSES.

BY C. D. O'CALLAHAN.*

In presenting to the Association our experience in the matter of removing obnoxious odors from drinking water, it is not our aim to claim a remedy for purifying water, but rather to explain what was done in the hope that the scheme or a modification of it may be of help in other localities to improve the character of drinking water. The general description of the well in question, may assist in giving an understanding of the situation.

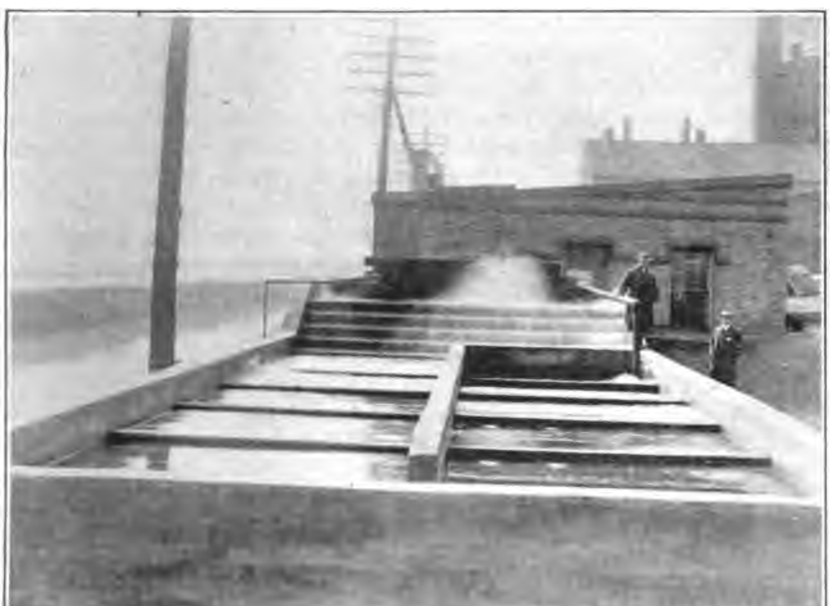
The contract for the well was let September, 1910, to the Ohio Drilling Company, and work was actually started in November of the same year. Specifications called for a hole of sufficient diameter to permit the insertion of the fourteen inch O. D. casing to a depth of two hundred feet. The hole was then to be reduced to a twelve inch bore, and this size continued to the bottom, if possible. When a depth of two hundred feet had been reached, fourteen inch casing was inserted and the twelve inch bore started from that point. At a depth of two hundred and twelve feet, oil was encountered in the shale rock and it was decided to remove the large casing and continue the bore of sufficient size to permit fourteen inch O. D. casing through shale rock. This was done and the large casing inserted to a depth of three hundred and twenty-five feet, sealed on the outside with Portland cement grout up to the surface of the ground. Drilling was then continued to a depth of about eight hundred feet, where, on account of caving material, one hundred feet of ten and five-eights inch liner were inserted. The top of this liner is seven hundred and ninety-seven feet, and the bottom is eight hundred and ninety-seven feet below the surface. The bore was then reduced to ten inches, and continued to the bottom at this diameter. The total depth of the well is one thousand five hundred and seventy feet.

No indication of oil appeared on the drilling tools at any time after inserting and sealing the large casing, and we had every reason to expect that all contamination had been cut off. When the pumps were started, instead of pure water we had a mixture of oil with a strong gas odor. Pumping was continued for some time with

*City Engineer, Joliet, Illinois.

the hope of exhausting this oil. In this we had little success, as the water remained unfit for use. It was decided to remove the pumps and insert another casing to a depth of about six hundred feet. We did this and on the bottom of the casing we put in, what is termed Wall Packer, its object being, by expanding against the wall of the well to prevent anything entering the well from above. The pumps were reset on their foundation and again started. The water, while improved a little, was still unfit for use. We then released the packer, pulled six hundred feet of casing out and reset it with the packer to a depth of seven hundred ninety-three feet, allowing the packer to rest on the ten and five-eighths inch liner, already mentioned. The pumps were started again but the water was very little improved. Pumping was continued for about one year with no improvement in the water.

It was the writers opinion, that if a means of aerating this water could be provided, the oil and gas might be removed. Together with



Device for Removing Gas and Oil from Well Water at Joliet.

Mayor Wood of Joliet, a visit was made to Urbana to consult and advise with Dr. Bartow of the State Water Survey. An analysis showed that the water contained oil. To determine whether aeration would effectively remove it, a small plant was constructed that would

take about one-sixteenth of the flow of the well. This was constructed in the form of steps with a tank at the bottom of the steps. The water from the well was allowed to splash down these steps and into the tank. At the base, the air from a small air pump was forced through the water and while the means were crude, they indicated that a properly constructed reservoir on the same general order would make the water usable. Accordingly, permission was asked of the City Council for authority to change the machinery at this well and install an air lift for blowing the well.

A concrete reservoir (See Figure) seventy-five feet long, twenty feet wide and seven feet deep was constructed, being divided into compartments of about six feet each, with a center wall passing longitudinally through the reservoir. At one end a series of steps was constructed, and the water from the well was delivered into a compartment from which it flowed over the series of steps, breaking up into drops. The partition, forming the several compartments in the reservoir, acted as baffles, the water passing over one and under the next one and so on up one side and back on the other, the partition wall in the center forming practically two reservoirs.

A system of pipes was laid leading into each compartment of the reservoir. These pipes were perforated and rested on the bottom of the reservoir. Through the pipes, air was delivered to each compartment at a low pressure simply allowing the air to bubble up to the surface, causing very little agitation on the surface of the water. The water as it was delivered from the well had a strong odor of gas and contained in emulsion some oil. This oil was brought to the surface by means of air flowing through it and was collected on the partitions and sides of the reservoir. The gas was released by the water being broken into particles over the steps and also by the air passing through the water. Considerable of the oil and grease collected on the sides of the first compartment in the reservoir, which receives the water after passing down the steps, and also of the next and succeeding compartments, so that when the water had traveled around to the last compartment from which the suction main of the pump drew it, no oil appeared on the surface or sides and the odor of gas was entirely eliminated.

The water from this well has been delivered into the distribution mains of the City for the past five months, and no complaints have been made from any of our citizens. In fact the water is as tasteless and odorless as any of the artesian water. This well delivers about one million gallons per twenty-four hours. The city had expended about twenty thousand dollars in drilling and equipping this well. By making this water fit for use, at least $20,000 was saved the city. The cost of the necessary change in machinery and the construction of the reservoir was less than three thousand dollars.

PUBLIC CONTROL OF WATER SUPPLIES IN ILLINOIS.

BY JOHN A. FAIRLIE.*

The law of waters and water rights in the United States has been for the most part regulated by the several states, subject, however, to the power of Congress to regulate interstate and foreign commerce (including the control of navigation and navigable streams in the interest of commerce), and to a greater control by the United States over waters on public lands and on international boundaries. In Illinois, as in most of the states, the earlier law on the subject was based primarily on the protection of private rights; and indeed in Illinois the public interest was—and in some respects still is—less clearly recognized than in many other states, and much less than in most foreign countries. But public regulation and control has come to be more definitely authorized in later years, both through local and state authorities. This public control has, however developed in a haphazard and unsystematic manner; it is vested in a variety of public authorities with overlapping and conflicting jurisdiction; while as yet there has been no serious attempt to deal with the subject in a comprehensive manner.

Judicial Rulings. Owing to a misunderstanding of early English decisions, and the literal application of this erroneous view of the English common law to vastly different conditions in this country, the Supreme Court of Illinois decided in 1842 that streams above the tide—even such rivers as the Mississippi, Ohio, Illinois and Wabash—were not navigable in law, and that the riparian proprietors could claim exclusive ownership in the soil and fisheries to the middle thread of the current, subject however to a public easement of navigation.(a)

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(a) Middleton v Pritchard, 3 Scammon (4 Ill.) 509-19 (1842);
Ensmeyer v People, 47 Ill., 384, 388 (1867);
Chicago v McGinn, 51 Ill., 266, (1869);
Braxon v Bressler, 64 Ill., 488 (1872).

The English cases had held that land under tidal waters was vested in the Crown, and that the beds of non-navigable streams above the tide were private property; but (as has been decided in recent English cases) left undetermined the ownership of the bed of navigable streams above the tide. Chancellor Kent appears to be responsible for the misunderstanding of the English law. 3 Kent's Comn. 427, etc.

Most of the American States and the United States courts have declined to apply this doctrine to the large fresh water rivers in this country, which are navigable in fact. Even in Illinois, the Supreme Court more recently has held that it is not applicable to fresh water lakes and ponds. (a) But the rule in the case of rivers has served to emphasize the rights of private owners as against those of the general public over these large bodies of water.

In the same year as the first decision as to the title of riparian proprietors to the bed of streams, the Illinois Supreme Court recognized an important distinction in the uses of water, in determining the rights of different proprietors. Water for domestic purposes, including water for stock, was held to be of greater importance than water for irrigation or manufacturing; and where there was not enough for all purposes, the latter must yield to the former (b). In a more recent case between the city of Elgin and a water power company, this ruling has been applied and extended, so as to recognize the uses of the general public as superior to those of private parties,—the court holding that the right of the public to take water for domestic, sanitary and fire purposes is paramount to the rights of the owners of water power to use the same for the purpose of propelling the machinery of their mills (c).

Early Legislation: In view of this later emphasis on the use of water for municipal purposes, it is worth noting that the first legislation in Illinois showing a public interest in the use of water had to do with its use for power purposes. The first General Assembly of the state passed in 1819 an Act in regard to mills and mill dams—taken from an earlier Act of the territorial legislature of Indiana, which in turn was derived from a Virginia statute. This act recognized the public interest in water grist mills by authorizing the condemnation of private property for the construction of mill dams; and at the same time established public control over such mills by regulating the rates of toll. These principles have been followed in later Acts and are still in force. In an Act of 1872, the right of eminent domain was extended to the erection of dams for saw mills and other public mills or machinery; but the Supreme Court has held that the earlier laws were based on the public character of grist mills, and that the condemnation of lands for dams for other purposes was unconstitutional (d). This ruling shows the attitude of the court in limiting the recognition of the public interest in the use of water for power purposes.

In the construction of the Illinois and Michigan canal and the im-

(a) Trustees of Schools v Schroll, 120 Ill., 509 (1887).
(b) Evans v Merriwether, 3 Scammon, 491, 495 (1842).
(c) Elgin v Elgin Hydraulic Co., 85 Ill. App. 182 (1889).
(d) Gaylord v Sanitary District, 214 Ill., 576 (1903).

provement of the Illinois and Little Wabash rivers, the State established direct control over these waterways for navigation purposes. Since 1872 the canal and Illinois river improvements have been under the management of a board of canal commissioners.

Municipal Powers: Until recent years most of the public control over waters in Illinois has been vested in the local authorities of cities, villages, towns and drainage districts. The beginning of legislation authorizing such local control is to be found in the special charters and Acts relating to local government, which cannot be here examined. But it may be noted that the cities and villages Act of 1872 authorized these muncipal corporations to construct and repair drains, sewers and cess-pools, to regulate the channel of water courses, landing places and anchorage of water craft, and "to provide for the cleansing and purification of waters, water courses and canals, and the draining or filling of ponds on private property, whenever necessary to abate nuisances." A year later, an Act of the General Assembly authorized cities, incorporated towns and villages to construct and maintain water works, and for this purpose to condemm private property (a), while it was further provided that the jurisdiction of such city, town or village to prevent or punish any pollution or injury to the stream or source of water for the supply of such water works shall extend ten miles beyond its corporate limits.

The revised township organization law of 1874 added to the powers of towns—to construct and keep in repair public wells or other watering places, and regulate the use thereof.

Drainage Authorities: The drainage laws of Illinois provide a curious medley of local drainage authorities, subject to no effective supervision. Under one Act, the county boards have power to preserve and improve ditches or drains constructed to drain swamp and overflowed lands donated to the county by the state; and for this purpose the county boards may form separate drainage districts and appoint a drainage commissioner for each district.

By another Act, to provide drainage for agricultural and sanitary purposes, the commissioners of highways of each town are made drainage commissioners; provision is made for forming drainage districts, union districts, special drainage districts, river districts, and districts by mutual agreement, and for recognizing voluntary districts; and the election of commissioners for most of these kinds of districts is authorized.

Still another Act provides for the organization of drainage districts for agricultural, sanitary or mining purposes, on petition and hearing before the county court; and for the appointment by the county court of commissioners for districts organized under this Act.

(a) By an Act of 1893 private water works companies are also authorized to condemn property for the construction of reservoirs and pipes.

Under these various and complicated laws hundreds of drainage districts have been organized throughout the state, with no supervision except that exercised by proceedings in the courts. These districts are in many respects more like private associations than public authorities. The only records as to the existence of districts have been scattered through the town and county offices; and there has been no complete list of districts even in a single county.

In addition to the large number of local drainage districts organized under these laws, two districts of special importance have been established under the provisions of optional laws framed with special reference to the districts concerned,—the Sanitary District of Chicago, and the East Side Levee and Sanitary District, for the region about East St. Louis.

STATE AUTHORITIES.

State Board of Health: The State Board of Health was established in 1877; and the second annual report of this board (for 1879) contains a report by the Secretary on the Pollution of Illinois River by Chicago sewage. This was followed by other and more detailed investigations, of which the following may be noted:

A report on the water supplies of Illinois and the pollution of its streams, in 1889.

Advance Notes of Sanitary Investigations of the Illinois river and its tributaries, 1900.

Report of Sanitary Investigations of the Illinois, Mississippi and Missouri rivers, 1904.

In recent years the State Board of Health has co-operated with the State Water Survey in investigations and reports on municipal water supplies.

Fish and Game Commission: The Fish Commission, established in 1879, which has been replaced by the Game and Fish Conservation Commission in 1913, has authority over fish and fisheries in the waters of the state. It enforces the laws regulating fishing and requiring the construction of fishways in connection with dams and other obstructions; and it maintains fish hatcheries and takes measures for the propagation and increase of food fishes.

Natural History Laboratory: The State Laboratory of Natural History, which is located at the State University, has in recent years, as a part of the natural history survey of the state, concentrated its work on a study of the effect of the pollution of the natural waters of the state upon aquatic biology.

State Water Survey: By an Act of 1897, the State Water Survey was established, under the direction of the trustees of the State University, to make a chemical and biological study of water supplies in the state for domestic and manufacturing purposes. By Act of 1911, the work of the survey was extended, by authorizing the employ-

ment of field agents to inspect water supplies and to make sanitary investigations and analyses of water. In addition to published reports of general investigations, a large number of special chemical and engineering investigations have been made of existing and proposed water works and sewer systems.

State Geological Survey: The State Geological Survey, established in 1905, has published several bullentins on water supplies in Illinois. Recently it has been charged with making surveys and studies of lands subject to overflow with a view to their reclamation. These reclamation surveys are made in co-operation with the Rivers and Lakes Commission, the United States Geological Survey and the United States Department of Agriculture.

Rivers and Lakes Commission: The Internal Improvement Commission of 1905 made extensive investigations relating to the projected deep water-way from Lake Michigan to the Gulf of Mexico, including the improvement of navigation routes, the development of water power, and the reclamation of lands. A joint-committee of the General Assembly of 1909 made an investigation of submerged and shore lands with reference to encroachments on the rights of the state on the public.

Following these temporary bodies, there was established in 1911 a Rivers and Lakes Commission, with jurisdiction and supervision over all the rivers and lakes of Illinois. The scope of the commission's authority covers a wide variety of work. It is to collect data as to public waters, in relation to navigation, water power, floods and the propagation of fish, to investigate complaints and prevent encroachments, to publish data for reclamation projects and to make plans for public reservations. Under the amended law of 1913, plans for works in public waters must be submitted to and be approved by the commission, and the commission is given power to subpoena witnesses and administer oaths. Appropriations also have been made to the commission for repairing levees on the Ohio river.

The powers of the Commission are however limited by a provision that its authority is not to affect the powers of the Canal Commissioners, the Sanitary District of Chicago, park commissioners, or structures erected by municipal authorities.

The Commission has collected a large amount of data, and has published a number of reports on water resources and on reclamation, navigation and harbor projects. Some complaints have been received, and a few plans for drainage and sewerage works have been submitted for approval.

Public Utility Commission: The State Public Utilities Commission, which was organized at the beginning of 1914, has jurisdiction over all private corporations or individuals owning or operating water or power plants, or acting as wharfingers, but its powers do not ex-

tend to municipal plants. It has extensive authority over reports and accounts; capitalization, mergers and intercorporate contracts; and rates, services and facilities. A certificate from the commission is necessary to authorize any new plant by a private company or individual; and the operation of the undertaking may be brought under its active control and regulation.

Need for Co-ordination: There seems to be clear need for a better co-ordination of the public authorities having jurisdiction over public waters and water supplies in Illinois. In addition to the local authorities in towns, drainage districts, villages and cities, there are no less than eight state bureaus having some authority and jurisdiction in relation to water. Each of the state authorities is substantially independent of the others, although there has been active co-operation between several of the state offices. Moreover none of the state bureaus have any effective supervision over the local authorities; and these in turn are legally independent of each other.

Public interest in water problems arises from a number of different factors; and it is by no means certain that all of these can be most effectively organized into one system of administrative organization. But there should at least be some readjustment and simplification of the present confusing medley of distinct and conflicting authorities. To provide for an effective co-ordination of public control, there is need for a thorough study of the existing laws relating to water problems so as to secure a general revision of such laws, a clearer statement of the powers of each state authority and their relations to each other and the local authorities.

ST. LOUIS RAPID SAND FILTER PLANT.

BY EDWARD E. WALL.*

St. Louis was probably the first city on the Western Continent to seriouly contemplate filtration as a method of purifying its water supply. In 1865, Mr. James P. Kirkwood, then chief engineer of the water works, was sent to Europe with instructions to investigate and study the processes of clarifying river waters there, so that some similar method might be adapted to Mississippi river water at St. Louis. Mr. Kirkwood reported to the Board of Water Commissioners the results of his investigation in 1865, and recommended slow sand filters, outlining a tentative design for their construction.

The following year the work of building new water works for the city was started at Bissell's Point, although Mr. Kirkwood does not seem to have altogether lost hope for the adoption of his filter project until 1869, when he writes, "The public mind of St. Louis, so far as it has been expressed, does not yet seem inclined to consider fiiltration important."

The new works, completed in 1871, were designed to provide for clarification by sedimentation only, four settling basins being built, each 277 feet wide by 600 feet long, and holding about twenty million gallons each. The city at this time was using about fourteen million gallons of water per day, so that the basin capacity was more than five times the average daily consumption.

In 1875 when the average daily consumption was slightly above twenty million gallons, an increase of settling capacity was deemed an immediate necessity. Two years later, under the new charter of the city, the water works were placed in charge of a Water Commissioner, Thomas J. Whitman, who at once called attention to the inadequate settling capacity, recommending the passage of legislation to reduce the waste of water, which he estimated at fifty per cent of the total pumpage. Year after year Mr. Whitman emphasized the necessity of enforcing ordinances prohibiting the waste of water, but found the people unconvinced by his logic, just as succeding Water Commissioners in later years have met with the same unreasonable opposition on the same subject. So that against his better judgment he was forced to build more pumps to keep up with the consumption. No

*Water Commissioner, St. Louis, Mo.

more settling basins were built and in 1884, during the extremes of temperature the water supplied the consumer was practically pumped directly from the river, since it passed through the basins so rapidly that little or no settlement took place. These conditions continued, increasing year by year in length and frequency of period, until in 1887, it was decided to locate new works at the Chain of Rocks.

In 1885 the Board of Public Improvements recommended building new works at the Chain of Rocks, and the construction of filter beds in the existing basins at Bissell's Point, with an alternate proposition of building the filters at the Chain of Rocks at an increased cost of $350,000.00. The filters proposed at that time were of the slow sand type estimated to filter two million gallons per day per acre, and of sufficient size to supply fifty million gallons per day.

From August 18th, 1885, until Feb. 23rd, 1887, tests were run on experimental filters, to determine the comparative value of the up-

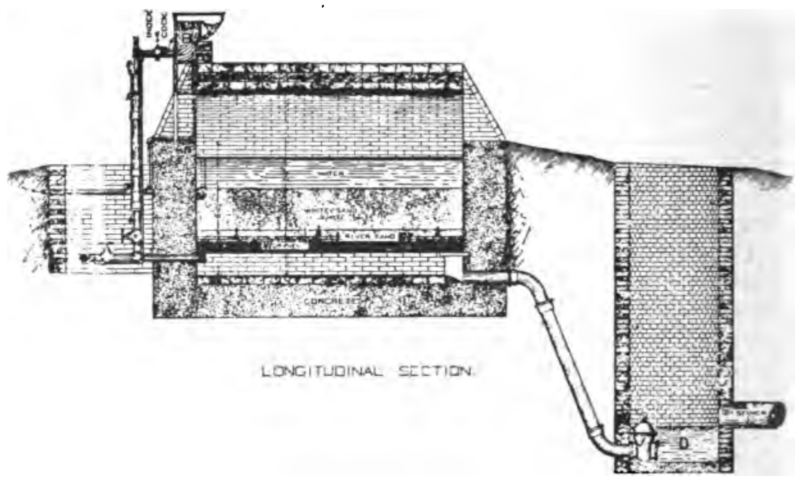

Fig. 1. Experimental Filter Plant, St. Louis.

ward and downward systems of filtration as applied to Mississippi river water at St. Louis. The raw water was applied to the filters without the use of any coagulant.

The data obtained in these experiments does not seem to have encouraged the authorities to undertake filtering the river water, so that the construction of the Chain of Rocks low service pumping station was designed with six settling basins, each 670 feet by 400 feet in plan, and with a combined capacity of 180 million gallons. This plant was put in service in 1894.

Again in 1900 plans for mechanical filters with a rated capacity of 120 million gallons per day were prepared, but the administration was not favorable to the scheme, principally because the people of the

State of Missouri, as well as of the City of St. Louis, had been prejudiced against the use of alum in baking powders, and the proposed use of alum as a coagulant in the preliminary treatment of the water supply was sufficient to kill the project. Thus filter construction in St. Louis was defeated for the third time in thirty-five years.

In 1903, the Water Commissioner, Mr. Ben C. Adkins, with the writer as his principal assistant was appointed by Mayor Rolla. Wells, with the express understanding that, before the opening of the World's Fair in May 1904, some scheme must be designed and put in operation to clarify the water supply. It is unnecessary to enter upon any history or description of the experiments and methods used during that year, since the fact has been well advertised and is generally known, especially among water works engineers, that the St. Louis water supply was clarified and purified without the use of filters and by a process of coagulation and sedimentation. Also it is equally as well known that the process has been in successful operation for about ten years. About two years ago it became evident that the capacity of the purification plant in use was too small for the treatment of the quanity of water consumed by the city. The eight years of operation of the purification process had also forced all of us who had been connected with the installation and development of the process, to reluctantly admit that it was not as efficient as filtration; that there were difficulties of operation that had not been satisfactorily overcome; that there were objections that could not be altogether removed. Whether to increase the capacity of the system by perpetuating the method in use, or by utilizing the machinery and basins for the preliminary treatment of the water, and then passing it through rapid sand filters, became principally a question of economy in first cost and operation. Careful estimates on the cost of increasing the capacity to 150 million gallons per day showed that to build additional basins, conduits, etc., to enlarge the present system would cost at least $250,000.00 more than to build a rapid sand filter plant to supplement the treatment in existing basins. It was also estimated that the cost of treatment and operation would be less with the filters. Considering also the unquestioned fact that the general quality of the water would be improved, and that a uniform clarity of water would be insured by filtration, there could be no hesitation in making a decision in favor of the construction of the rapid sand filters.

In January 1912, the Water Commissioner was authorized to prepare plans and specifications for changes and additions to the existing works at the Chain of Rocks, including the filter plant, so as to bring the working capacity up to 150 million gallons per day.

The general lay-out of the Chain of Rocks works, giving the location of the filter plant, head house, mixing chamber, conduits and connections, with reference to existing structures, is shown in Fig. 2.

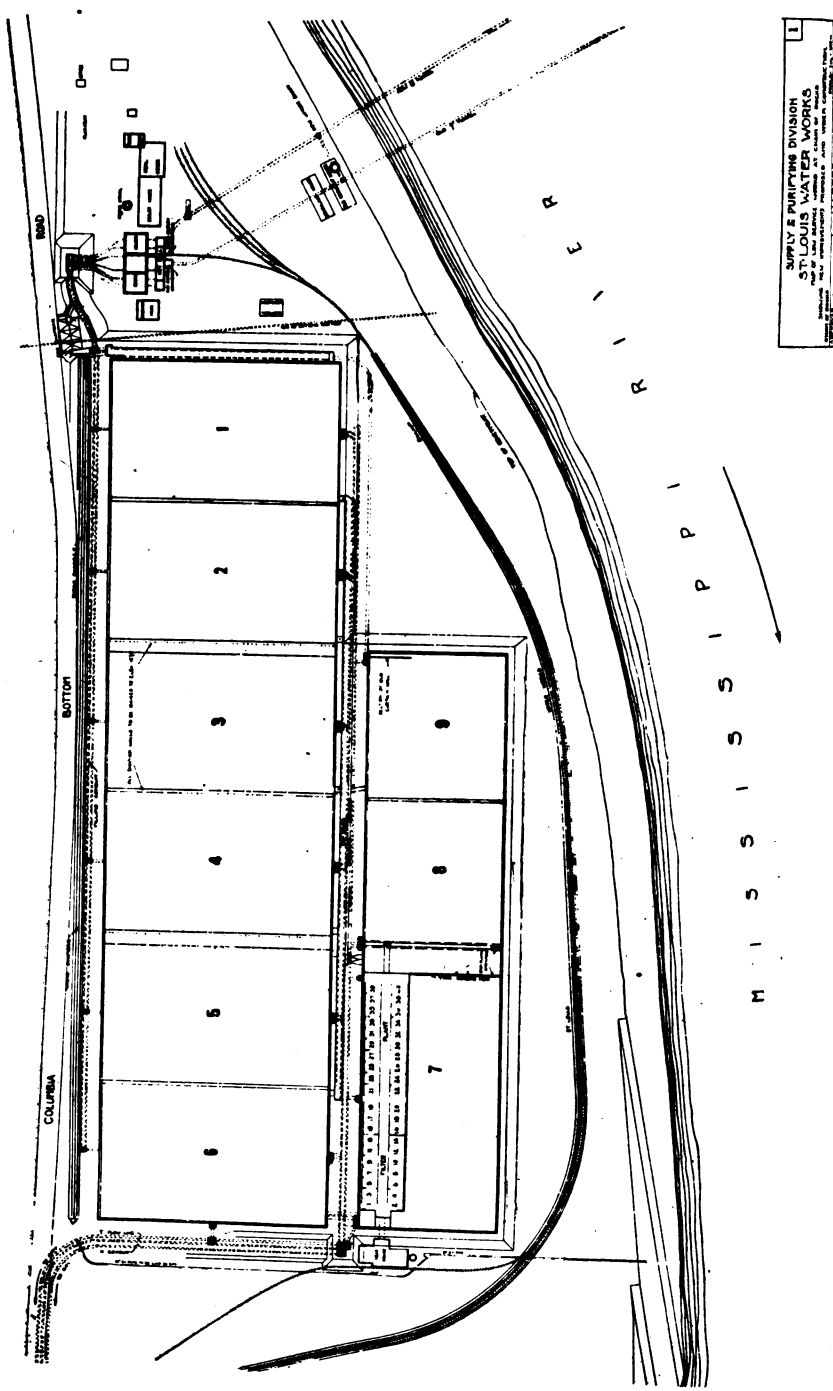

Fig. 2. General Plan, Purification Works, St. Louis.

The filters are located in the western portion of basin 7, occupying a space approximately 700 by 140 feet. The filters were located in the basins, rather than on ground outside for several reasons, for example the space taken from the basin could be readily spared, since ample basin capacity for coagulation and clarification would remain, construction could proceed more rapidly since no excavation was necessary, better and more convenient arrangements for utilizing existing conduits and making new basin connections could be had, and on the whole the cost would be decreased by such a location.

The design provides for forty filter units, each 50 by 28 feet in plan, supported on concrete columns 20 inches square, spaced 11 feet centers north and south and 10 feet 3 inches east and west.

On the original basin floor inverted concrete arches were laid to distribute the foundation loads of the columns. The filter boxes rest on the reinforced concrete floor formed by leveling up the groined arches joining the tops of the columns. Each filter box is poured as a monolith, the concrete mixture being 1: 2: 4, with 25 lbs. of hydrated lime added for each barrel of cement, for the purpose of making the boxes water-tight. The concrete in the columns and arches is composed of a mixture of 1: 2½: 5. Screened and washed gravel has been used throughout for the coarse aggregate.

The strainer system consists of the channel type, in which the drains are formed by and between concrete ridges, and covered by perforated strainer plates anchored to the concrete by bronze bolts and bars. Along the center of each half of each filter unit is formed a collecting channel, 28 inches wide by 5 inches deep, into which all the small lateral drains 3 inches wide by 5 inches deep empty. Four ten inch openings in the bottom of each collecting channel are connected by cast iron pipe to the effluent conduit.

The water will be filtered through 30 inches of sand and 12 inches of gravel. The gravel will be placed on the filter bottom in three layers, the bottom layer of 5 inches in depth, composed of gravel, ranging in size from ¾ to 1½ inches in diameter, the second layer 4 inches in depth, size from ⅜ to ¾ inch, and the top layer 3 inches deep, size from 3-16 to ⅜ inch. The sand will have an effective size from 0.40 to 0.50 mm., and a uniformity co-efficient not greater than 1.65.

The gallery between the filters contains the effluent conduit, 15 feet wide and 4½ feet high, over which lies the 36 inch cast iron wash water pipe, and above that is the inffluent flume, 15 feet wide and 10 feet deep, into which the water is drawn at each end of the filter house from basins 7 and 8. Both the influent and effluent flumes are built of reinforced concrete. The cover of the influent flume will be the operating floor of the filter house. Each filter has a 24 inch connection to the wash water pipe. All drainage and wash water from the fil-

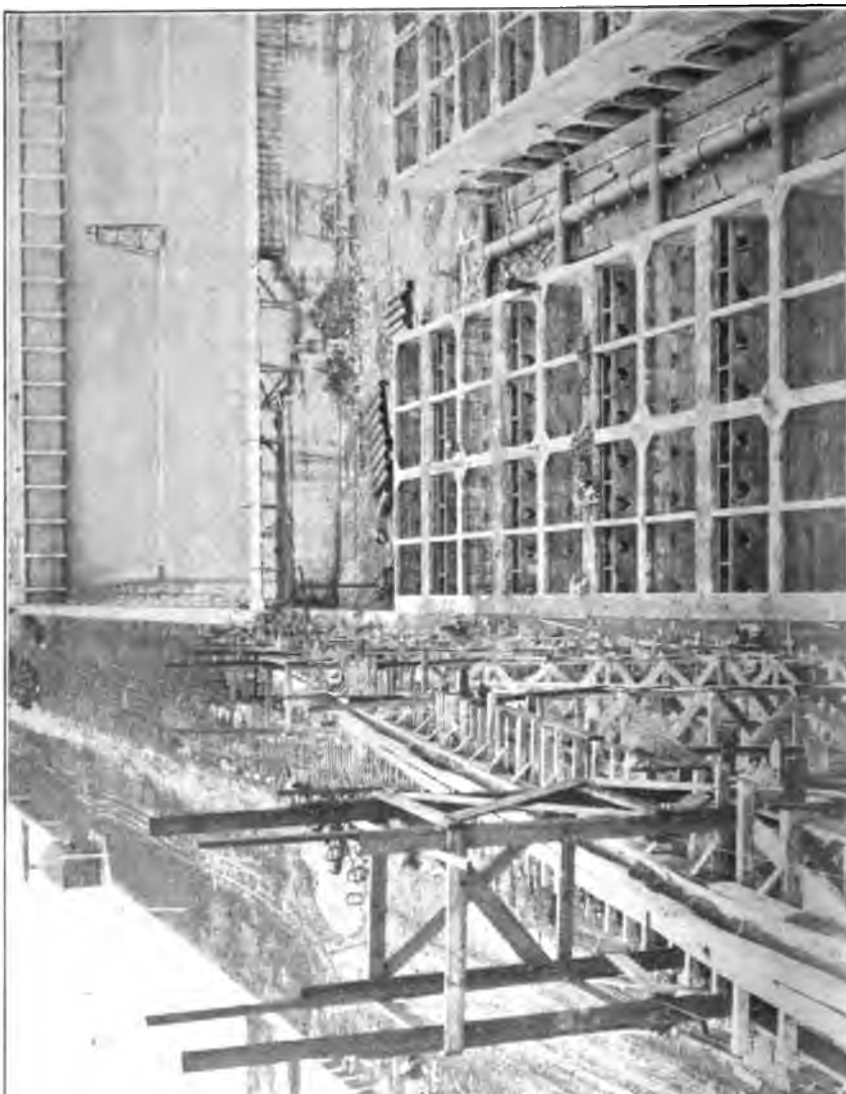

Fig. 3. Concrete Filter Boxes and Gallery.

ters is carried through 30 inch sewers to the main sewers and thence to the river.

The rate of flow through each filter will be maintained by a rate controller placed on the 24 inch effluent pipe. Each controller can be set to maintain any desired rate of flow between 1,500,000 gallons and 5,000,000 gallons per 24 hours, regardless of the difference in head on the two sides of the controller, which difference may amount to as much as 14 feet.

The registered flow shall not vary more than three per cent from the actual flow below the 2,500,000 gallons daily rate, nor more than one and one half per cent. when the rate is above that amount. These 40 individual controllers will be connected to a master controller, which

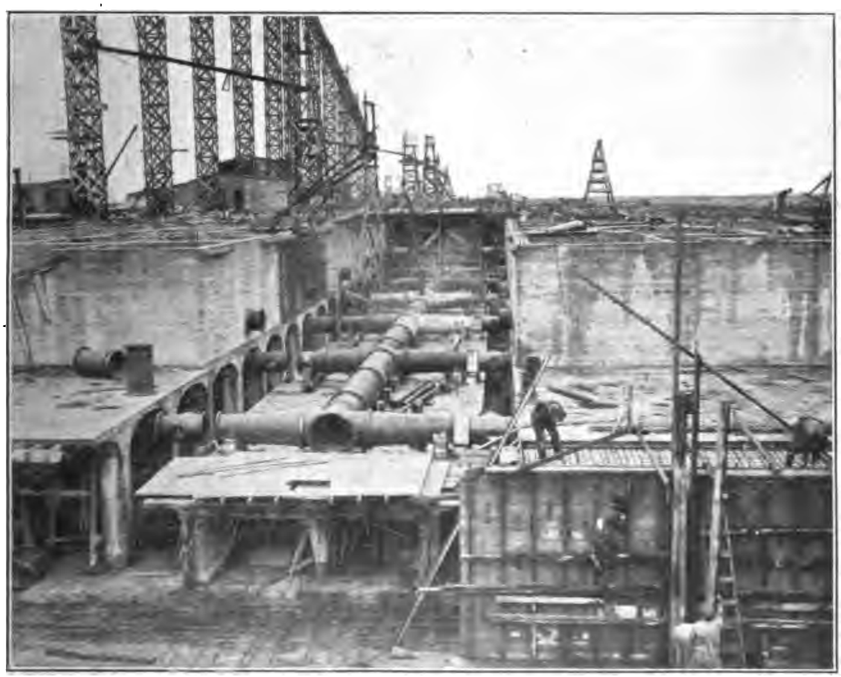

Fig. 4. Gallery between Filters, Showing Effluent Conduit and Wash Water Pipe.

when set at any desired rate of flow, will automatically set the individual controllers on each filter at the same rate.

The operation of each filter will be handled from an operating table on the central gallery floor. These tables will be equipped with valve levers, gages and sample pumps. The 24 hour records of the height of water on the filter, the loss of head through the filter, and the

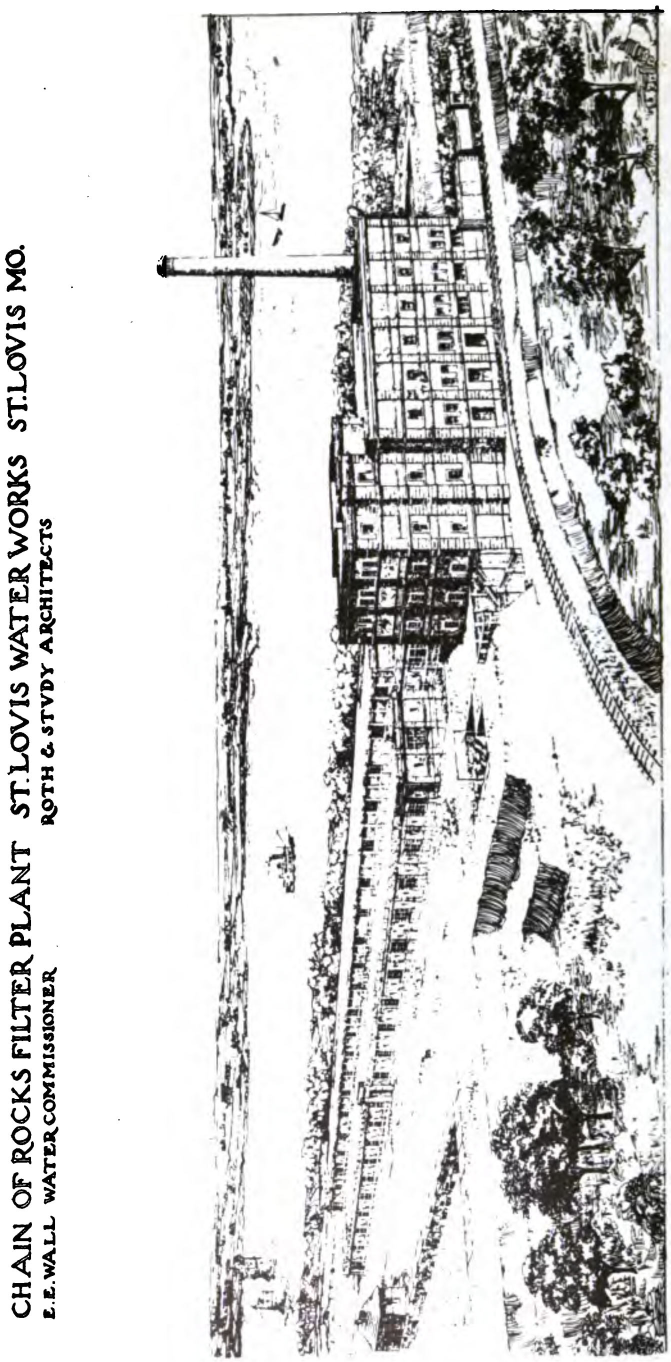

Fig. 5. Filtration Plant, St. Louis, Mo.

actual quantity of water passing through the controller will all be kept on one sheet. A recording gage will also show the elevation of water in the effluent conduit at the center of the filter house.

Venturi meters with recording attachments will be placed on the 36 inch wash water pipe and on the outlets of the collecting conduit. These meter records, together with the individual records of each filter, will afford independent measurements of the quantity of water passing through the plant, and which again may be checked against the pumping records, which are also made by Venturi meters.

The filter house, which will entirely cover the filters will be built of concrete with metal window sash and frames. The ceiling beams will be almost 12 feet above the operating floor at the side walls, the slope of the roof from the central gallery being one half inch to the foot. On the concrete roof will be placed the ordinary tar and gravel covering. The building which covers an area of 699 by 134 feet will be heated from a steam plant in the head house. The current for lighting the filter and head houses and for operating motors will be furnished from a generator house, located at the south end of the pumping engine house. This generator house will be a brick building 58 feet by 66 feet conforming architecturally to the existing buildings at the pumping station. The machinery will consist principally of two 250 K. W. steam driven units.

The head house is to be a four story concrete building located 34 feet south of the filter house. On the first floor will be three 150 horse power tubular boilers, four alum solution tanks, two alum solution pumps, three 12 inch centrifugal pumps for filling the wash water tanks, two 6 inch pressure pumps for operating hydraulic valves, a four ton refrigerating plant for manufacturing ice for the department, a store room for hypochlorite of lime and liquid chlorine, and a small machine shop; on the second floor will be located an office, a small laboratory, six alum mixing tanks, wash rooms, lockers and store-room; two wash water tanks, each 50 feet in diameter and containing 175,000 gallons of water, will occupy the greater part of the third and fourth floors. The dome shaped covers of these tanks will form a portion of the roof of the building. There will be space on the third floor for the solution tanks for hypochlorite of lime and for the liquid chlorine apparatus, and on the fourth floor the space will be utilized for hypochlorite mixing boxes, and storage for alum. Alum, coal and other supplies will be delivered in cars on a switch alongside the head house. Alum will be unloaded from the cars into an elevator chute, from which it will be elevated and conveyed to the storage bins on the fourth floor.

The basins as shown in Fig. 2, excepting 7 and 8, will be used as primary coagulating basins, and will be operated in parallel, the present system of operating in series being abandoned. Before the water

reaches these basins and before any chemicals are used, it will pass through a grit chamber 70 feet by 100 feet where the heaviest of the matter in supension will be precipitated. As the water leaves the grit chamber it enters the first channel of the mixing chamber where it will receive the charge of lime. The mixing chamber consists of four parallel channels, each 7 feet wide by 11 feet deep, through which the water may be directed in series or in parallel. Used in series the water will be made to travel about 10,000 feet between the grit chamber and the filling conduit, while by using the channels in pairs only one half that distance will be traversed. The object in varying the distance through the mixing chamber is to be able to approximately regulate the carrying capacity of the chamber to the variable quantity of water being pumped so as to maintain the velocity sufficiently high to prevent settlement in the channels.

The effect of the passage of the water through the mixing chamber is to insure the thorough mixing of the milk of lime with the water and also to allow a longer time for the softening action of the lime before the sulphate of iron is added. This will result in an estimated saving of probably 30 per cent. in chemicals, because of the elimination of loss due to incomplete chemical reactions. The water on leaving the mixing chamber and entering the filling conduit, will receive the charge of sulphate of iron. The inlets from the filling conduit to each basin will be baffled to prevent direct flow across the basins. The water will be drawn from the primary basins into a concrete collecting conduit, located between the two sets of basins. From this conduit, it will be delivered and measured through two Venturi meters, with 56 inch throats, into a chamber 75 feet wide, extending the full distance across the north end of basin 7. As the water enters this chamber, it will receive any secondary treatment that may be necessary, before it is drawn into basins 7 and 8. The addition of hypochlorite of lime or liquid chlorine when necessary may be made just before the water goes to the filters or these chemicals may be applied to the filtered water as it leaves the filter house.

The rated capacity of each of the forty filter units is 4,000,000 gallons per 24 hours, or 160,000,000 gallons per day for the plant. This output may be increased to 200,000,000 gallons per day, should it become necessary to supply this amount of water.

The contract for the concrete substruction, filter boxes, conduits and connections, was awarded to the McCormack-Coombs Construction Company of St. Louis on April 18th, 1913, for the sum of $225,-023.10. Because of the location of the filters in basin 7, it was possible for the contractor to design a comparatively simple plant for mixing and placing concrete. A switch track was laid along the basin wall, so that material could be dumped from cars into bins above the mixer which was placed in a pit 22 feet below the surface of the

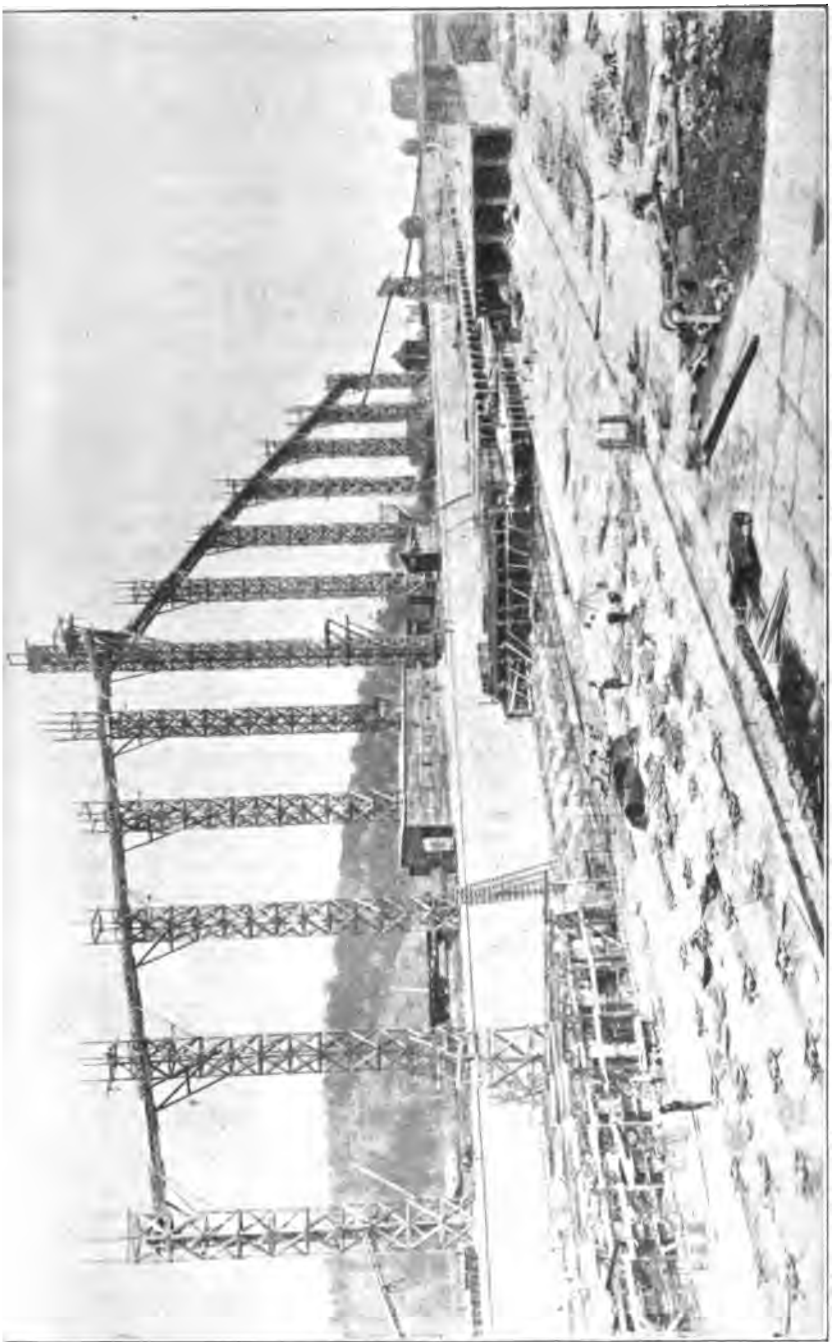

Fig. 6. Towers and Chutes for Delivering Concrete at St. Louis Filters.

ground. One of the bins holds about 14 cars gravel, the other about 10 cars of sand, while the adjacent cement shed will contain 1500 barrels of cement.

The concrete mixer discharges into a skip operated in a tower 119 feet high. From this main tower chutes run for the entire length of the filters, a total of about 700 feet. Concrete can be taken from the main chutes at any one of the twelve towers and carried to any part of the work. The grade of the main chutes is 20 per cent. They are made of wood, lined with sheet iron, are 12 inches in width and depth and span 45 feet between towers. The moveable chutes are made of steel in one piece, and are 12 inches wide by 10 inches deep.

The velocity with which the concrete flows from the main tower to its destination is about four hundred and eighty feet per minute.

The mixing and placing of concrete was begun on July 17th, 1913 and up to Feb. 1st, 1914, a total of 155 working days, 14428 cubic yards of concrete have been poured. This includes the entire substruction, 38 filter boxes, the effluent conduit and the greater portion of the influent conduit. 24 filter boxes were poured during 27 consecutive days in December and January, each box containing 107 cubic yards.

The cost of erecting form work for the walls, columns and arches was $1.65 per cubic yard of concrete, and for the effluent conduit $1.55 per cubic yard.

Following is the list of contracts let, and the estimated costs of the work necessary to complete the plant:

1.	Filters	McCormack Coombs Const. Co.	$225,023.10
2.	Filter Equipment	Pittsburg Filter Mfg. Co.	398,200.00
3.	Filter House	McCormack Coombs Const. Co.	89,730.00
4.	Head House	Estimated Cost	185,000.00
5.	Waterproofing Basins 7 and 8	" "	50,000.00
6.	Raising Division Walls	" "	85,000.00
7.	Generator House	" "	50,000.00
8.	Mixing Chamber	" "	160,000.00
		Total	$1,243,953.00

Contracts for the last five items will be let within sixty days, and it is intended to have the plant ready for operation by November 1st. All contracts will require completion before that date under heavy penalties for over-time. This plant when completed will be the largest mechanical filter plant in the world.

LOCATING LEAKS IN WATER MAINS BY MEANS OF THE WATER HAMMER DIAGRAM.

BY MELVIN L. ENGER.*

When the valve at the end of a long pipe line is closed suddenly, great pressures may be caused. The term water hammer has been applied to this phenomenon. If the valve could be closed instantly all of the water in the pipe would not be stopped at the same instant. The layer nearest the valve would stop first, then the next layer and so on until the impulse has traveled through the entire pipe line. As each layer of water is brought to rest its pressure will of course be increased. The velocity of the transmission of the pressure wave will be the same as the velocity of transmission of sound in the water in the pipe, and will vary between 3400 and 4700 ft. per sec., depending upon the material of the pipe and upon the ratio of the thickness to the diameter of the pipe.

It has been found that for any given pipe, the amount of the water hammer pressure is a constant times the extinguished velocity. The value of this constant (also called the water hammer coefficient) varies directly with the velocity of transmission of the pressure wave, and for cast-iron pipe used for water supplies has values between 45 and 63. For cast-iron pipe between 6 and 16 inches in diameter, the average value of the constant is about 55. That is, the water hammer pressure caused by the sudden closure of a valve at the end of a long pipe line, in pounds per square inch, is 55 times the velocity of the water in the pipe before the valve was closed, in feet per second.

Fig 1a represents a pipe line in which there is a leak. The flow between the source (reservoir or large pipe) and the leak is $v - w$ feet per second, and between the leak and the valve is v feet per second. Fig. 1b shows the conditions in the pipe line a short time after the valve at the end is suddenly closed. The velocity of the water near the valve has been extinguished and its pressure increased hv lb. per sq. in. (h being the water hammer coefficient). If the distance from the valve to the leak is l feet and the velocity of propagation of the pressure wave is Z ft. per sec., the pressure wave will reach the leak l/Z seconds after the valve closed. Since the original pressure at the leak allowed a quantity of water equal to Aw cu. ft. per sec. to escape, it is evident that a higher pressure will cause a

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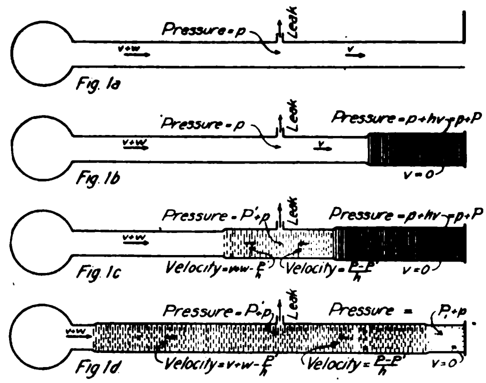


Diagram Showing Condition of Pressure and Velocity at Various Times after the Closing of the Valve.

greater quantity to flow. The extinguished velocity between the leak and the source will therefore be less than v ft. per sec. Hence the water hammer pressure generated in this part of the pipe line will be less than hv lb. per sq. in. A wave of reduced pressure will therefore travel from the leak toward the valve. Fig. 1c shows the conditions a short time after the pressure wave has passed the leak. The

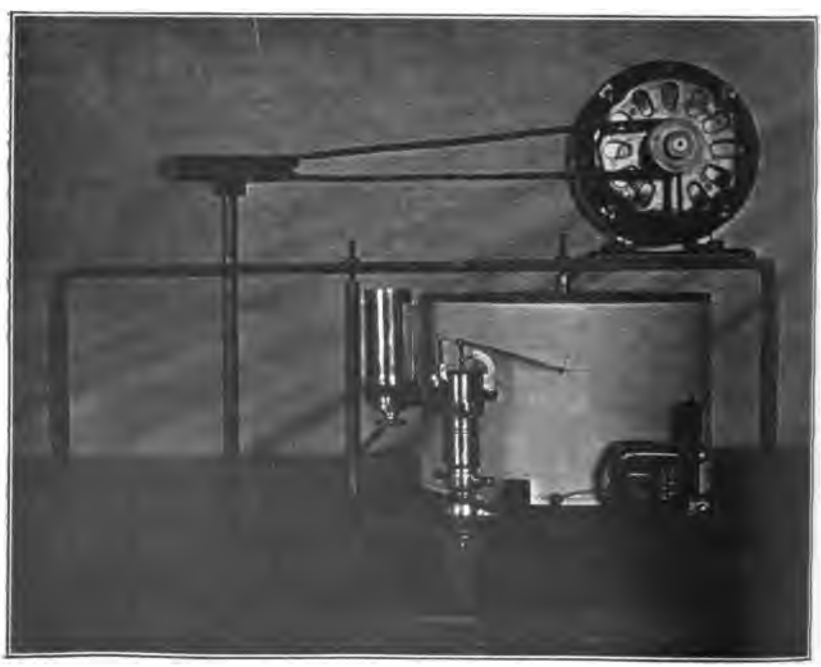


Fig. 2. Apparatus.

wave of reduced pressure will reach the valve $2l/Z$ seconds after the valve closed. Fig. 1d shows the conditions a short time after the wave of reduced pressure has reached the valve.

The water hammer diagram is a graphical representation of the pressure in the pipe line near the valve for a time after the valve is closed. In the experiments made by the writer the diagram is obtained by having the pencil of an indicator trace on a sheet of paper wrapped around a drum driven at a uniform rate by an electric motor. Another pencil attached to an electro-magnet makes a time record. A photograph of the apparatus is shown in Fig. 2.

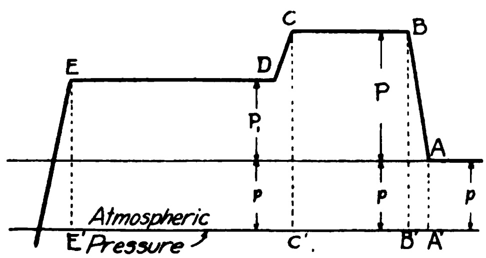


Fig. 3.

Typical Water Hammer Diagram Showing Effect of a Leak.

Fig. 3 shows the characteristic features of a water hammer diagram taken at the end of a pipe line in which there is a leak. The first rise of pressure as the valve begins to close is shown at A. The indicator pencil reaches B when the valve is fully closed. The pressure then remains practically constant until the effect of the leak is registered at C. The distance A′C′ represents the time required for the pressure wave to travel from the valve to the leak and back to the valve. If the velocity of transmission of the pressure wave is known, the distance from the valve to the leak is easily computed. The difficulty in the use of this method is in the determination of the velocity of transmission (Z) of the pressure wave. The velocity of the pressure wave will vary somewhat, according to the amount of air in the water. Another method which avoids the necessity of determining the value of Z is as follows: When the indicator pencil reaches E, the first relief of pressure due to the source is felt. The distance A′E′ therefore represents the time required for the pressure wave to travel from the valve to the source and back to the valve. If the length of the pipe line from the valve to the source is L, the distance from the valve to the leak can be determined by proportion.

$$l : L :: A'C' : A'E'$$

In the writer's experiments, much more consistent results were obtained by this method than by the use of the velocity of transmission of the pressure wave and the time required for the pressure wave to

go from the valve to the leak and return, as scaled from the diagram.

The quantity of water discharged from the leak can also be determined from the water hammer diagram. The expression for the velocity of flow in the pipe due to the leak is:

$$w = \frac{\frac{P - P_1}{h}}{\left(\frac{P + P_1}{2p} - 1\right)^{0.5} - 1}$$

P is the amount that the pressure is increased due to water hammer, P_1 is the amount that the pressure at the valve is above the original pressure after the return wave from the leak reaches the valve; p is the original pressure at the valve; h is the water hammer coefficient.

The following values are taken from experiments made by the writer in 1906. The last two were measured from the second diagram shown in Fig. 5.

Calculated Distance. Feet	Actual Distance. Feet
64	72
70	72
371	381
385	381
375	381
262	265
265	265
116	113

A number of values have been computed from the equation, and the results have been plotted in Fig. 4. It was assumed that $P = 55$ lb. per sq. in., $p = 40$ lb. per sq. in., and that $h = 55$. It

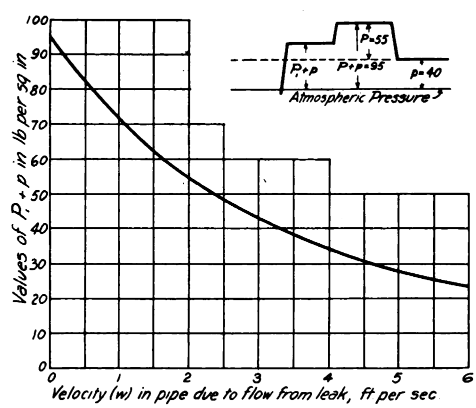


Fig. 4.

Diagram Showing the Drop of Pressure on Water Hammer Diagram Due to Leaks of Various Amounts.

will be seen from an examination of the curve that even small leaks will produce a noticeable fall of pressure on the water hammer diagram.

The first suggestion that the water hammer diagram could be used to determine the location of a leak was made by Professor Joukovsky as the result of a series of experiments made in 1897 and 1898 for the waterworks department of Moscow, Russia. He published a monograph (Stoss in Wasserleitungsrohren) in 1900. A translation of this paper, somewhat modified, was published in the Proceedings of the American Waterworks Association in 1904. Experiments were made by the writer in 1906 on a 2-inch pipe 730 feet long in the Hydraulic Laboratory of the University of Illinois. Fig. 5 shows two diagrams taken at that time.

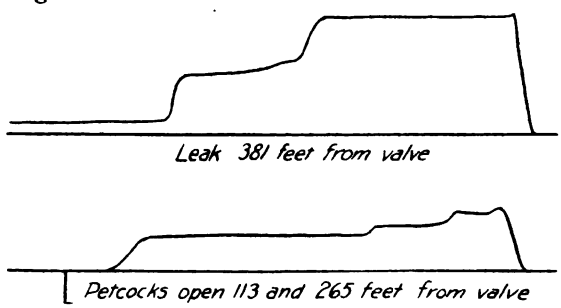


Fig. 5

Water Hammer Diagram Showing Effect of Leaks, taken on a 2-in. Pipe Line, 730 Feet Long.

In using this method for determining the location of a leak, the following suggestions are made. The quick closing valve should be at the end of the section of pipe to be tested. This can be accomplished by tapping the main close to a valve, the valve in the main being kept closed during the experiments. The pipe leading from the main to the quick closing valve must be large enough that a water hammer pressure at least as great as the static pressure can be caused by the sudden closure of the valve. The indicator should also be connected at this point of the main, or to the pipe containing the quick closing valve. If possible, the method of proportional distances should be used. The distance to the source (large main) should be measured. A hydrant partly open will make a good reference point in case the main on which the experiments are being made is very long. When the method of proportional distances is used it is not necessary to know the speed of the paper. It is only necessary that the paper travel at a uniform speed while the diagram is being taken.

An apparatus called the "pulsograph," using the above principles for locating leaks, has been patented. It was described before the meeting of the New England Waterworks Association in September, 1913.

REMOVAL OF ANCHOR ICE BY MEANS OF AIR.

BY L. A. FRITZE.*

It is amusing to note that no matter how old or how many times a certain chestnut has been under discussion, there is always someone who thinks he is "springing" something new when he attempts to resurrect it. Before going into this subject, I wish to apologize to the older heads, who probably have thrashed out this problem years ago, for taking up their time in listening to me; yet, there may be some one here who is having trouble, as we have had, and will be glad to know that he is not the only one who has found his intake pipe choked off, and his water supply exhausted in the "wee small" hours of the morning.

The subject of anchor ice, needle ice, and other names designating the same thing, some of which are not permissable in print, is a subject so old, that it needs very little kindling to bring back vividly to many a water works man, some very trying times. I will not attempt to go into the subject of anchor ice itself, but will simply try to explain a method we have been using at the Moline Water Works to remove it from the intake pipe after its formation.

Many and varied have been the methods proposed for the removal of anchor ice, each plant practically having its own, which has been successful to a greater or lesser degree. The use of air is not new, yet the success of this method at our plant is such that the troubles usually encountered with ice, bother us no more.

The water is supplied to the plant through two intake pipes, a 20 inch, 350 ft. in length, and an 18 inch, 3500 ft. in length. The water flows by gravity to a well and is then pumped to the filter plant. The intake pipe with this air attachment extends into the river, open and unprotected at its mouth, there being no crib or other device built about the pipe.

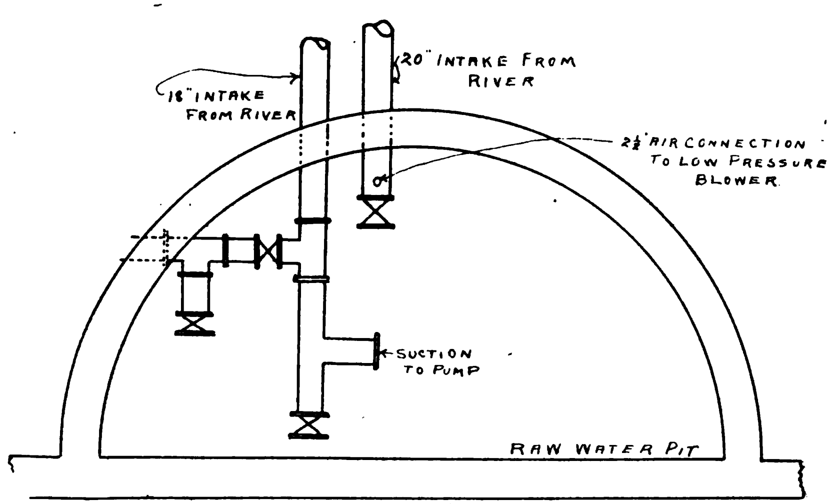
A centrifugal pump was so arranged that it could be connected to the 18 inch line, so that in a pinch the water could be drawn through this line until the well was filled, and then the valve on the choked 20 inch line opened, letting the full pressure bear against the obstruction. The depth of the well is about 20 feet, and the head usually obtained by this means is about 15 ft.

This system, while helpful at times, could not be relied upon. As long as the 18 inch line remained open, things were satisfactory, but just as soon as the ice began to choke, the plant was at a standstill.

During the past year, the Chief Engineer, Mr. Buck, has attempted to improve the plan by connecting to the 20 inch line the

*City Chemist, Moline, Ill.

blower used to air wash the filters. The blower used is of the Root make, giving a large volume of air under low pressure, that is, up to about 10 lbs. At times for very short periods, the pressure has been forced up to 30 lbs. The connection between the blower and the line is through a 2½" pipe connected to the intake pipe, near the raw water well end. On the nights when the temperature conditions indicate a slight freezing, the height of the water in the raw water well is carefully watched. When the level begins to drop, the blower is started and in a very short time the line is completely cleared. At times when the line has been choked tight, the blower has always cleared it in a few minutes. The pressure used at the worst stages, runs about 10 lbs. per sq. in. From the figure, the layout of the raw water well and the air connection can be more clearly seen.



Removal of Anchor Ice By Means of Air.

Temperature, seems to be the only factor in the formation of anchor ice. It is claimed by some that the appearance of this ice occurs only on certain nights, for example, nights following clear days, or a clear night. Clear days and cloudy days alike seem to have little special control over the ice problem in the Mississippi River so far as we have been able to observe. The main trouble usually becomes noticeable after midnight and remains until day break.

There are a number of plants where the local conditions are such that the use of this method is not warranted, but at such places usually, the ingenuity of the engineer has successfully combated the troubles. However, at some places where the unprotected intake is at the mercy of the weather, the use of air will probably be much handier, as well as more efficient, than the reverse flow of water.

UNDERGROUND MOVEMENT OF CONTAMINATION.

RY ADOLPH GEHRMANN, M. D.*

Every raw water supply is at times in danger of contamination. It may be by the direct entrance of discharges or in an indirect manner from surface washings or drainage into bodies of water, or the supply may be drawn from an area of underground pollution. Some of the known observations in relation to this latter type of epidemic origin may be of interest here. Most epidemics of water-borne disease come as a surprise to a community. For years a more or less contaminated supply may be in use without the introduction of the exciting bacteria to start an epidemic. The most subtle and insidious form of contamination is that which is entirely underground and one that only the experienced can appreciate in all its possibilities. Often a superficial inspection fails entirely to give a proper conception as to what is taking place under ground. The ground water may be moving in just the opposite direction to that indicated by surface inspection. The rate of movement of ground water is a guess until something is learned about the strata underlying a district. The filtering action of various layers is widely different. Compact surface soil filters best, while loose gravel will have the least action as a filter. The continuous passage of contamination will soon destroy whatever there is of value in the soil as a filter. A few feet of soil may filter at one time, while a contaminated zone of many hundred feet may be formed in time from a relatively small but continuous supply of polluted water.

The ground water is a definite part of the physical geography of a district. It moves in accordance with well-known types of strata formation, either of rock or clay, or porous layers. Such movement of ground water must be a condition that is extensive and uniform in the deeper layers of the earth, where the strata are continuously saturated. We often forget that water has been seeking its level for ages in these layers and has long ago adjusted itself to the conditions that exist. Temporary changes in levels occur, but the main movement, however, goes on about the same all the time.

The movement of contamination under ground has been studied by a number of observers. One of the earliest observations is that

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of Daubrée, in 1848, who recorded the change in quality of well water 300 meters distant from a leak at the gas works at Strassburg. Fodor, 1893, expressed the opinion from observations that materials added to water are continuously spread horizontally and pushed ahead by the masses of water following. In 1872 the movement of ground water was shown by applying salt as an indicator in the investigation of the classic Lausen epidemic. In this instance it seems clearly to have shown the course taken by the infecting bacteria for a distance of about one mile.

But dissolved substances cannot be taken as indicating the movement of particles. As in this Lausen instance, starch grains did not follow the course of the contamination.

In 1896 Pfuhl experimentally showed that known bacterial cultures would pass in a short time through a distance of twenty-four feet in gravel, one hour for B. prodigiosus, and two hours for a phosphorescent vibrio.

In 1896 Alba, Orlandi and Roudelli used Bacillus prodigiosus to show the movement of contamination in ground water in connection with an investigation of the reasons for the periodic contamination of the water supply of Turin. They reported prodigiosus culture finding its way to the water gallery through a distance of two hundred meters, when poured over an area of ground this distance away.

Fraenkel about this time investigated the filtration action of soils.

Instances of the movement of contamination in ground water are not common. The usual type of epidemic of typhoid, diarrhea or cholera is that of surface contamination from more or less direct pollution from the flow of sewage or drainage into the water supply.

In 1893 I investigated an epidemic at a Michigan summer resort, where it was found that the pollution escaped from cess-pools and infected the club-house well. These cess-pools were located at the foot of a ridge back of the club-house where the private cottages were. The row of cottages was about half a mile long, but they were well apart. During the summer there were several cases of fever in these cottages and one patient died. The cases were among visitors returning home, and it was found that these cases were persons who had boarded at the hotel. At the hotel well water was used, while the cottages were supplied from another source by a pipe line. The cess-pools were apparently so located that the drainage would be away from the cottages and hotel, but the ground water movement was in a general direction towards the lake and under the hotel. The entire substratum was sand and gravel, which allowed the ground water to pass easily.

Again, in testing the quality of water from wells supplying the

workmen's camps during construction of the drainage canal, at the request of Dr. Martin, sanitary inspector of workmen, it was found that these wells were generally contaminated. The wells were driven wells, two hundred to three hundred feet deep, but were located too near the old canal and the line of new construction. We concluded that the ground water of the entire area was more or less contaminated. It is very probable that numerous fissures and gravel pockets made it easy for the contaminated water to pass to the deeper levels.

Under ordinary conditions the ground water does not become so easily contaminated. Fraenkel's experiments showed that most of the bacteria were caught at the surface and retained, and that those passing deeper soon died because of unfavorable conditions. It is very probable that the porosity of a soil is the most important factor in the spread of infection. It is the particle-carrying groups of bacilli that are dangerous and whenever the porosity is such that particles do not pass, the danger of spreading infection rapidly diminishes. Gravel, coarse sand and fissures in rock make underground contamination a menace to health. The distance that it may move in any locality is uncertain until there is evidence by experiment as to presence and extent of such a permeable layer in the involved area.

DISCUSSION.

Dr. Burrill: When the Water Survey first started under the direction of Dr. Palmer they went about selecting certain types of wells for pretty continuous examination and the one selected as the best type of shallow well happened to be the one at my residence on the next street corner from where we now sit. The house is on high ground sloping away from the house and from the well back of it. We had used that well for a good many years and became attached to the water. When the city water was first put in it was not as good as it now is and we did not like it for drinking purposes and with this continuous examination made by the Water Survey we thought we were right in continuing to use the water. No trouble had been found with the water and it had been examined every week for a year and a half. The soil here from two to three feet below the surface is underlaid with a layer of sand and gravel. My well had been dug 22 feet to hard-pan from which the water rose 4 feet so that the surface level stood uniformly 15 feet deep. I had taken pains to fill in behind the wall, thinking possibly the shallow well might be detrimental to drinking purposes, filled in behind wall with tenacious blue clay, and thought the water reasonably safe.

About this time of the year, after a heavy rain, Professor Palmer sent out the query "What in the world is the matter with the water

in your well". They had found it badly contaminated with organic matter. No explanation could be given except that we had applied on the lawn a good coat of stable manure up to within 100 feet of the well. Though the surface slope was decidedly from the well to the highest place where the manure was applied, we came surely to the conclusion that we were drinking a dilution of the manure fertilizer. The well was soon filled up.

EXPERIENCES WITH WAUKEGAN WATER SUPPLY.

BY W. J. ALLEN.*

At the last meeting of the Association, the writer presented a paper describing the hypochlorite installation in use by the city of Waukegan, Illinois.† This plant has now been using hypochlorite for nearly two years. Careful records have been kept of the operating results, and a discussion of the experiences encountered may be of interest.

The raw water is received through a 24-inch intake extending 4,000 feet into the lake. There is also an emergency intake, of 36-inch pipe, extending 600 feet into the lake. The sewage from the city enters the lake at a point relatively near the intakes, and at times the raw water is seriously contaminated.

Daily laboratory tests are made to control the treatment. The table shows the turbidity and bacterial counts of the raw water and

TREATMENT OF LAKE MICHIGAN WATER, WAUKEGAN, ILLINOIS.

	Turbidity Pts. per Million			Bacterial Count*						Gas Form-ers**		Avail. Chlorine Pts. per million		
				Raw Water			Treated Water			I cc. Raw	Tr't			
	Average	Highest	Lowest	Average	Highest	Lowest	Average	Highest	Lowest	Days	Days	Average	Highest	Lowest
1913														
July	5.	5	5	4056	6720	1520	117	490	0	12	0	.328	.428	.234
August	12.4	73	5	1643	7980	217	330	1680	1	25	4	.546	.805	.389
September	30.6	210	5	751	3360	100	289	2960	1	27	9	.546	.832	.370
October	25.8	180	5	1251	4850	64	104	1440	1	8	0	.493	.651	.296
November	70.3	325	10	1410	5360	145	32	430	1	17	2	.634	.768	.545
December	66.	260	23	1429	4760	309	14	35	2	10	1	.543	.800	.329
1914														
January	74.	200	30	2271	5760	640	22	90	3	10	3	.481	.681	.277
February	33.	100	10	5618	16960	225	15	146	2	14	0	.558	.832	.250
	40.			2303			115			50%	8%	.516	.724	.336

*Agar, 20°, 72 hrs.
**Dextrose broth—37½°, 48 hours.

the treated water, the number of days that gas formers were present in the raw and in the treated water, and the parts per million of available chlorine used in the treatment during the eight months from July, 1913, to March, 1914.

*Chief Engineer, Waukegan Water Works.
†Proceedings 1913, 203.

The raw water has a minimum turbidity of 5, a maximum of 325 and an average of 40. The bacterial count on agar at 20 degress for three days shows a minimum count of 64, a maximum of 16,960 and an average of 2,303 per cubic centimeter. Tests for gas formers are positive in about 50 per cent. of the total number of tests. In summer nearly all the tests are positive and in winter a much smaller proportion are positive.

The bacterial results upon the treated water show an average count of 115 per cc. Of 243 tests for gas formers in one cc. samples during this period, 19 were positive or in other words 8 per cent. of the tests for gas formers were positive.

The amount of bleach used is about .5 p.p.m. The bacterial condition of the raw water changes so rapidly that it is very difficult to regulate the rate of application of bleach from the bacterial count. It takes at least twenty-four hours to get the needed information. Consequently the starch iodide test has been found very useful. By continually making this test upon the treated water, it has been found that a certain depth of blue color, indicating a proportional amount of hypo, will give the required treatment. If the color is too deep an overdose is apparent and if the color is too faint, satisfactory bacterial efficiency will not be obtained. The treated water is tested with starch and potassium iodide every four hours. The procedure is indispensable to us.

The conditions on our lake vary and the changes are frequent. At times a large dose of hypo is needed, and within a few hours it may have to be reduced twenty-five or thirty per cent. High winds, strong agitation of the water, sewage, the approach and departure of schools of fishes, will cause this change in hypo treatment. If the only method to govern the treatment was the count on plates, we would be unable to handle the treatment with any degree of success, as changes might take place before the bacterial results would be available.

It is necessary to make frequent laboratory tests to keep proper control of the treatment and I believe it is possible to keep the water free from the taste of hypo to such an extent as to cause no complaint from the consumers. We seldom hear complaints from our citizens. This can not be the case, however, unless one is attentive to treatment and keeps the hypo plant running evenly at all times.

DISCUSSION.

Jennings: It is one thing to install a good hypo plant and another thing to keep operating it properly. Of all the hypo plants that I have installed, I know of none that has had the care and attention that has been given by Mr. Allen to the one at Waukegan. At the time

I was there, Mr. Allen was looking forward to the introduction of the eight hour shift in place of twelve hour shifts. Instead of working eight hours since that time, he has been putting in more time than under the old regime, testing his hypo solution, planting bacterial samples, counting plates, etc. As a result the bacterial reduction has been very good, B. Coli in the treated water has been very scarce and Typhoid Fever in Waukegan has been almost eliminated.

Bartow: The results at Waukegan are certainly gratifying. It seems to me that the most significant thing in the table which Mr. Allen has shown us is the turbidity in the water. It is the best argument for a filter plant at Waukegan that I have seen. There were months when the average turbidity was 60 and at times when the lowest turbidity has been at least 30.

TOO MUCH WATER.*

BY JOHN W. ALVORD.†

The great floods of March, 1913, which devastated the states of Indiana and Ohio, will always have a direct and intense interest for engineers, and the importance of having the data carefully recorded and studied is obvious. Up to this time the main initiative, which has been taken in obtaining the detailed facts, has been of municipal origin. A government board is working on the general problems and it is hoped will fully develop all the further lines of inquiry which should probably be made. It is generally agreed that the main lessons to be learned from the recent great floods are as follows:

First, that there should be some authoritative and adequate public control of our streams which will prevent encroachment by bridges, buildings, populated territory, railroad embankments and dangerous levee systems, not only upon the low water channels, but upon the flood plains as well.

Second, that where relief from existing encroachment is required, it should be accomplished through legislation authorizing the formation of flood protection districts, preferably covering entire watersheds, so that each problem as a whole can be given proper technical study. The cost of flood protection work should be apportioned in some fair relation to the benefits and value of the affected interests.

Third, that, while Indiana and Ohio cities have recently received a severe object lesson, there are many other cities and towns in this country which have so encroached upon the adjacent river beds as to be already in peril. They should not be permitted to await a physical demonstration of their danger, but should be aroused to the problem of protection from destructive floods.

Fourth, the studies at Columbus and Dayton, as far as made, indicate that radically different methods of treatment are often required for communities apparently similarly situated.

No generalization as to the relative merits of reservoir versus channel improvement methods will take the place of thorough investigation and study of the local situation and sound deduction from the facts thus disclosed.

*Presented November 19, 1913, before the Boston Society of Civil Engineers. J. Boston Soc. C. E. 1, 85-108.

†Consulting Hydraulic and Sanitary Engineer, Chicago.

THE STORM OF MARCH, 1913.

With these general conclusions in mind, I desire to invite your attention to some of the main features of two flood districts in Ohio which it has been my opportunity to study. These are the Scioto at Columbus, necessarily including Delaware, and Chillicothe, and the Miami River and its branches at Dayton, covering Troy, Piqua and Miamisburg on the Miami watershed. The flood story in all these places is essentially the same. Insidious encroachment followed out for years, not only upon the low water channel, but upon the flood water plain, had so reduced the channel capacity created by nature that only about one-quarter to one-third of the flood water could be accommodated in the regular channels. The remainder of the flood rose until it overtopped the levees and swept through populous areas with destructive velocities which demolished houses and caused death and widespread suffering.

The great storm which created this condition is worthy of special notice. It had been preceded in the same month by storms of considerable strength which passed over the same area, and on the morning of March 20 a storm developed over the Rocky Mountain and Great Plains states which moved rapidly eastward and, joining during the afternoon of March 24, a second storm, which had developed over the Southwestern states, covered an elongated area enveloping the Ohio Valley watershed continuously for a period of sixty hours or more. It was accompanied by excessive rains and the most widespread and devastating floods of modern times. They combination of these storms caused them to pass in a southeasterly direction over Central Ohio. The greatest intensity of rainfall centered directly on the divide which separates the waters flowing north into Lake Erie from those flowing south into the Ohio River, then moved southeasterly down those streams, undoubtedly accentuating the flood waves.

In the territory above Columbus and Dayton the greatest precipitations were observed at Bellefontaine, Marion and Richmond, Ind., where about 11½ ins. were recorded for the four days, and on Tuesday, March 25, from three to four inches fell all along the upper portion of the Scioto and Miami watersheds, coming on top of the several inches which had fallen on the two previous days. Some three inches fell on the Scioto River watershed above Columbus even after the crest of the flood had passed the city, which accounts in part for the slow decline. No other storm as great in area and intensity as this has been recorded in this country, outside of the Pacific slope, but it must be obvious to any one who studies the flood water plains of these and other rivers that great storms of this kind have occurred and flood waves have been produced which were fully as great, if not

greater, than those recorded in Ohio and Indiana in March, 1913. The normal flood plains of the rivers were occupied fully as they have been time and again during the recent geological past. When we remember the comparatively limited time over which records of great storms have extended in this country, we must realize that one of the urgent lessons which the engineer has to learn is not to place too great reliance upon them.

It is interesting to note the accumulated rainfall at Columbus and Marion, hour by hour, during the four days in which it took place. The rise is fairly constant in both cases, although on the final day the excessive amount of over 11 ins. at Marion appears in comparison with the 7 ins. which accumulated at Columbus.

It is no wonder that the astonished inhabitants of Dayton and Columbus could not understand where such a vast quantity of water came from. Rumors of reservoirs having broken circulated in both cities, and the presence of reservoirs on their upper watersheds gave foundation to them. None of the younger generation had seen floods cause such serious damage, and even the older people had not seen floods of such magnitude. The Ohio State Board of Health is authority for the statement that in Ohio alone 430 lives were lost, 104 municipalities inundated, 20,000 homes completely destroyed, and 35,500 other homes rendered uninhabitable.

Some one has estimated that the amount of water which fell in Ohio and Indiana during this storm would raise the level of Lake Erie, with an area of 10,000 sq. miles, approximately 4 feet.

THE FLOOD AT COLUMBUS.

It is of interest to contrast the local situations in Dayton and Columbus and, for this reason, it is desirable to describe more particularly the topographical features which contributed to the especial disaster at each of these places.

At Columbus, the Olentangy and Scioto rivers, emerging from parallel rock gorges in which they have flowed for twenty-five miles or more, unite just above the West Side of the city upon a broad flood plain nearly a mile in width. The slopes of both rivers above this point are much steeper than below, so that water is launched upon the broader and flatter flood plain with greater rapidity than it can be properly carried away. The Scioto River crosses the flood plain just north of the populated part of the West Side, uniting with the Olentangy near the east side of the flood plain, passing close to the rising ground on the east side near the central portion of the city, then around what is locally called the "Bend," thence winding through the flood plain from side to side.

Levees from ten to fifteen feet high were raised along the northerly

part of the West Side after the flood of 1898 to protect it. Thus confined, and reduced in width by encroachments, the river channel around the Bend had a capacity less than one half of that needed for a flood such as occurred in March, 1913.

The natural result of this condition was the ponding of the waters above the dikes until they were overtopped and washed completely away in many places. The flood waters swept through the numerous breaks with great swiftness and demolished buildings, tore up pavements and caused great general destruction and loss of life.

It should be remarked that the buildings on the west bank of the river around the Bend are built upon made ground which encroaches upon the river channel proper, and that there are also numerous bridges, many of which were destroyed. The capacity of the Scioto around this Bend was hardly more than 50,000 sec.-ft. at high flood stage, but after the scouring of its bottom with many depressions 25 ft. or more in depth, and with increased slope, it perhaps carried a maximum of about 70,000 sec.-ft., while the flood flow at the crest of the flood is estimated to have been 140,000 sec.-ft.

THE FLOOD AT DAYTON.

In Dayton the situation was likewise especially endangered by the fact that four rivers converge just above the center of the city: the Mad River, with 680 sq. miles; the Miami, with 1,160 sq. miles; the Stillwater, with 650 sq. miles; and Wolf Creek, with 50 or 60 sq. miles; all having a combined catchment area of about 2,550 sq. miles. The channel through the central part of Dayton, being only about 500 or 600 ft. in width, could barely carry 85,000 to 90,000 sec.-ft., while the estimates of the recent flood maximum are from 240,000 to 260,000 sec.-ft.

Of the six bridges spanning the main stream at Dayton, four reinforced concrete arch bridges held like adamant, while the steel bridge at Fifth Street and the railroad girder bridge were carried away. A hydraulic engineer ventured out upon this latter bridge, during the highest stage, and measured a difference of five feet in the levels on the upstream and downstream side. This was in part due to the tremendous amount of drift which accumulated there.

The first water invaded Main Street in Dayton at 9 a. m., March 25; one hour later it was 3 ft. deep at the same place and by one o'clock it was at least 10 ft. deep. The work of cleaning the city after the flood went down was of great magnitude. Estimates of the amount of silt deposited over the town vary from 4 to 6 ins. In some places where excessive deposits occurred they were removed with steam shovels. People were obliged to push the ruined contents of their lower floors out into the streets, and the city was busy for several months after the flood carting the accumulations away.

DAMAGE AT COLUMBUS.

The value of the property in the flooded district of Columbus is estimated to have been fifty million dollars, and the direct loss caused by the flood, not including indirect damages, is estimated at seven and a half million dollars.

Some idea of the devastation can be had from the following summarized statement taken from the Columbus Report:

The entire city was without water for twenty hours.

The West Side was without water for about one week.

All the public schools were closed for three days and the nine public schools on the West Side were closed for about five weeks.

The levees of the West Side were not entirely repaired for over four months and the railroads were unable to operate on their own tracks for periods ranging up to about one month.

Street car service throughout the entire city was abandoned for two days and badly crippled for about one week, and no street cars were operated on the West Side for ten days after the flood. Communication across the river by car was not reestablished for a month.

Cleaning the streets of débris and removing flood deposits consumed the best part of two months, and the repaving of damaged streets was still going on three months after the flood.

A very large portion of the houses on the West Side were so damaged that at least a month elapsed before they could be restored to habitable condition.

RESERVOIR PANICS.

With the perils and distress of the flood, there came to nearly all the inhabitants of both Dayton and Columbus a panic produced by the rumors that important reservoir dams had given way. After the strain, which nearly everybody involved had been under, it is not strange that even strong-minded people should have been ready victims of such a rumor. No one could understand where such a vast quantity of water could have come from. In Dayton, the water was at least 8 ft. higher than any one could remember it to have been before, and the immediate thought was that the reservoir dams upon the upper watersheds had given way and added to the already dangerous floods. An untold amount of mental suffering was produced for some hours in both Dayton and Columbus by this fear. It is a question whether the terror inspired by these panics will permit those populations to calmly contemplate the construction of great reservoirs on the watersheds above their cities for the purpose of protection. Where they are plainly the most economical and efficient way of controlling floods, their dams must be very ample in their proportions and stable in their design if they are to receive the confidence and approval of the people.

Another engineering lesson which can be profitably drawn from

these flood scenes is the necessity of providing free waterway under bridges for débris. All great floods are drift-laden, and houses, barns, fences, haystacks and wreckage of all kinds quickly lodge where an insufficient waterway is provided, still further reducing the area.

DETAILS OF DEVASTATION.

One of the factors which aggravated the flood conditions and contributed to the loss of life in Columbus was the extensive track elevation which had been recently completed there. The elevated tracks were on embankments of considerable height and stability which the flood overtopped in many cases, but usually the water found egress through the subways, where currents were created which must have reached velocities of from 18 to 25 ft. per sec. Such velocities, operating for hours, were particularly destructive to the municipal improvements and the buildings in their vicinities. Great holes 15 to 20 ft. in depth were washed out at such places in the paved streets; houses were swept away and vast masses of loose rock of large size were carried great distances and spread to a depth of 3 or 4 ft., sometimes over areas of several acres.

The flood of 1898 in Columbus, while of considerable magnitude, did not have anywhere near the devastating effect of the flood of March, 1913, due largely to the fact that in former times the levees above the town were comparatively low, and that no track elevation existed.

After the flood, most of the people of the flooded West Side district were compelled to live for many weeks in their second stories. Many of the houses, especially those of brick, were rendered uninhabitable for months by the saturation of their walls.

Horses were generally drowned when caught within the flooded districts. They seemed to have no sense which would guide them to the higher grounds, although having strength enough to swim for hours in strong currents before becoming exhausted. But the submerged automobiles rose to the occasion. A little cleaning and they were ready to do splendid service in relieving distress, conveying food supplies and doing work that could never have been done otherwise to rehabilitate the city.

RAILROAD DESTRUCTION.

The damage to the railroads was very great throughout the entire flooded area and traffic was suspended for a week or more. In an instructive booklet issued by the Pennsylvania Railroad a diagram is given showing the interrupted and abandoned tracks of their lines west of Pittsburgh, and this gives a good idea of the area and magnitude of the flood disturbance.

As a typical instance of railroad destruction, attention may be called to the Big Four Railroad's new cut-off lines below Dayton. This great work had just been completed at an expense of some millions of dollars when it was put out of commission by the flood of March, 1913. Below Miamisburg, where a high embankment crosses the flood plain of the Miami River, the swift currents created were instructively interesting. The largest part of the flood passed under a new girder bridge over the Miami River, but a considerable flow, perhaps 25,000 to 50,000 sec.-ft., found its way under a heavy double track bridge over the Miami and Erie Canal. Here the velocities must have been very great, probably at times reaching 20 to 25 ft. per sec., as indicated by the upstream and downstream high water marks. A great pit was excavated below the bridge and large bowlders and thousands of tons of stone from it were distributed over a wide field below with interesting regularity, showing a gradation which would do credit to the best sorting screens ever designed.

These phenomena have raised the question as to whether some rough rule could not be formulated which, from the weight of the stone moved, would give the velocities created in the water, but amid the necessity for more important studies, this interesting side phase of the subject has not received attention.

There was deposited below the Big Four bridge a pile of assorted gravel many hundred feet long and from 8 to 12 ft. high, which was dropped at this place by the retardation of excessive velocities. It is interesting also to note the scour which took place around the waterworks station at Richmond, Ind., and the ability of sod, as compared with large bowlders, to resist erosion.

ROCK EROSION AT COLUMBUS DAM.

Perhaps no other effects of this great flood show the intensity of the forces at work as do those resulting from the overflow at the Columbus storage dam. It is roughly estimated that the flood in its passage over this dam and through Columbus would, theoretically, have created over a million horse-power, the larger part of which was dissipated in internal work of the rolling water. At certain points, however, where this power was not so dissipated, its effects were of a most marked character. Some idea of the external work which was performed by the water after passing over the crest of the dam can be had by examining the channel just below as it appeared when the river was again low. Great rocks, some of over three tons weight, were quarried from the bottom of the river, carried downstream some hundred feet, and piled up in a dike. (Fig. 1.) The rock at this point is laminated limestone, lying in nearly horizontal strata.

A survey which has been made indicates that in places at least 10

feet of solid ledge rock was removed from its bed. It does not appear that the stability of the dam is much affected so far, as it is unusually strong both in weight and profile for the heads which it has to carry, but to any engineer who is constructing dams, and who has had to do with

Fig. 1. Erosion at Columbus Storage Dam.

the enormous forces created by large quantities of water rolling over crests, these facts are certainly significant and instructive, and may be profitably recalled when designing similar structures.

FLOOD MEASUREMENTS.

In taking up the problem of flood protection, the first study necessarily was to determine, as nearly as possible, the amount of the flood of March, 1913. At Dayton, this work is in charge of the Morgan Engineering Company, and it has been difficult. The best opportunities for measurement have been found only in the difference of head which the flood marks show above and below certain bridge openings, through which the entire flood, or nearly the entire flood, passed.

The Big Four bridge below Miamisburg, which was badly wrecked by the flood, is one of the places in which this determination has been attempted. The chief difficulty lies in the fact that we have no means of knowing, with any degree of satisfaction, the varying cross-section below the low water line, which was materially increased during the flood by the enormous scour. This scour wrecked the foundations of the piers and created deep elongated pits in the bottom of the river, leaving mounds in some cases upon which the bridge piers stood. These and other embarrassments make it difficult to determine, within close limits, what the flood flow in the Miami may have been. At

Columbus, the passage of the entire Scioto flood over the crest of the storage dam, with the hourly records of its height, afforded data of unusual interest and well defined the quantities of the flood flow.

The Columbus dam is 500 ft. long on the crest, about 30 ft. high, and is founded upon rock. Its profile is very ample, as it was the intention at some time in the future to raise its crest to a considerably greater height. The original design of the spillway provided for 6 ins. of run-off in twenty-four hours from the watershed above. Such a run-off would have caused the water to flow over its crest to a depth of something like 22 ft. Actually the flood of March, 1913, reached a head of 12.8 ft. on the crest, as measured by a gage on the upstream side.

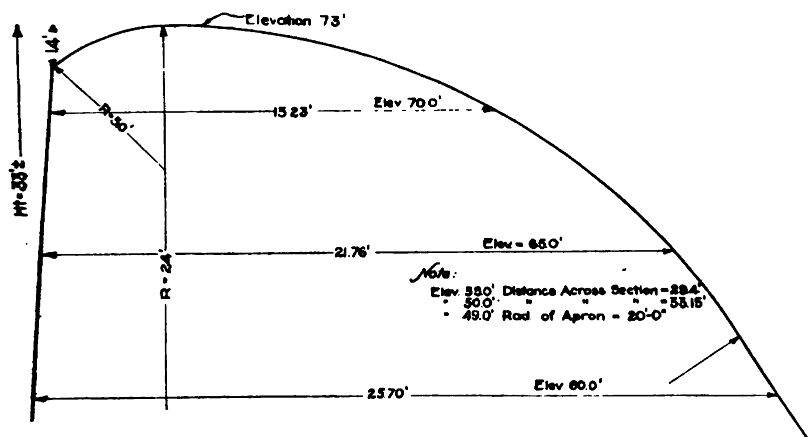

Fig. 2. Form of Crest, Columbus Storage Dam.

It became a matter of importance and interest to study carefully all of the available data showing the value of the coefficient "C" in the Francis formula, for crests of this type and for this head, the profile of the Columbus dam being as shown in Fig. 2. Besides the Columbus dam, there was available the profiles and accurate data of the La Grange dam (which is somewhat similar), the Austin dam and certain dams which were used in the experiments by the United States Board of Engineers on Deep Waterways at Cornell University. It should be noted that the greatest head for which we have definite information occurred on the La Grange dam, upan which flows of over 7 ft. in depth have been measured.

It is not possible to review here the methods of reasoning which were adopted in determining this question. Those who are especially interested will find them fully stated in the report on the Columbus

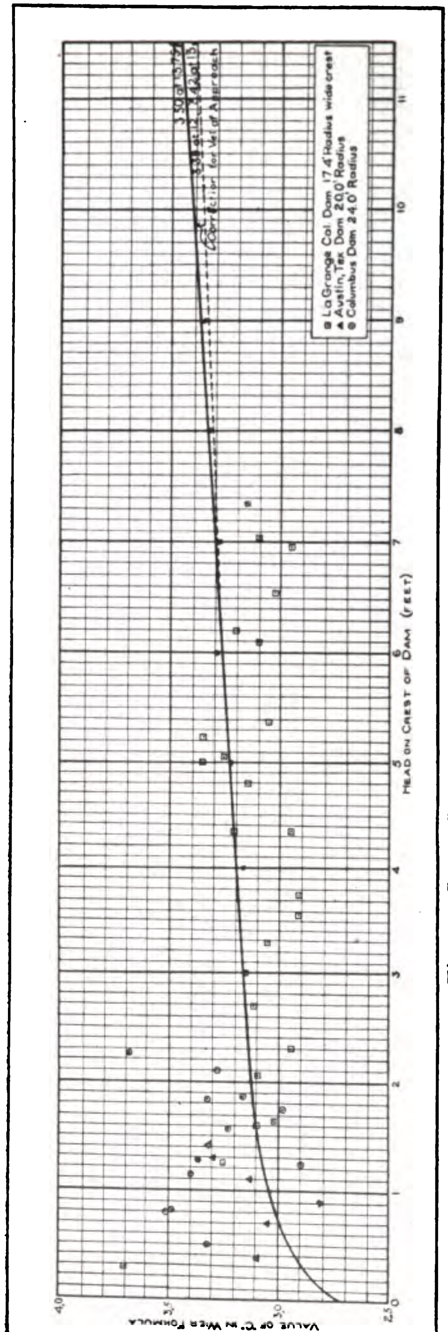

Fig. 3. Curve Showing Value of "C" in Francis Formula.

flood protection. The general conclusion, from an analysis of all the available information, was that the coefficient was not increased to any marked degree by reason of the special type of crest, and that heads of 12½ ft. on the Columbus dam would not produce a coefficient of more than 3.5 for the Francis formula. The curve which was finally concluded to be warranted, and which has a lower value than that assumed by a number of engineers just after the flood, is shown in Fig. 3.

One very convincing argument in favor of the belief that this determination of C was conservative lies in the fact that applying greater coefficients than those indicated by the curve would have resulted in demonstrating that more water passed over the Columbus dam during the flood period than fell as rain on the watershed above. The average rainfall on the watershed above the Columbus dam was 9.34 ins., while the run-off, compiled by the above curve of coefficients, was 8.63 ins., giving a run-off of 93 per cent. of the rainfall. This is a high rate of run-off, but to decrease it would be to decrease the value of the coefficient C materially below what it is believed a conservative investigator would be willing to assume.

At Columbus, it was also necessary to measure the flow of the Olentangy River. The best opportunity for this was at Delaware, about 25 miles above Columbus, where at a bridge opening through which the entire flood passed the water marks above and below were distinctly recorded. The bottom of the river being rock, there was no considerable change of cross-section, except that due to the destruction of the center pier of the bridge and some erosion of the roadbed of the Pennsylvania Railroad, which passes under the western span. The conclusions as to the flow of the Olentangy are not based upon so secure data as were available for the flow of the Scioto, but it is evident that the flow of the Olentangy was considerably greater than that of the Scioto per square mile of drainage area, as might be expected from its smaller watershed, the final conclusion being that the two rivers combined gave 89 sec.-ft. per square mile of drainage area. The Upper Scioto from the measurement at the storage dam yielded 77 sec.-ft. while the Olentangy measured at Delaware, yielded 115 sec.-ft. per square mile of drainage area.

EROSIVE CURRENTS.

As has been said, the marked loss of life and the most serious destruction in Columbus occurred in the vicinity of the levee breaks and the subways where the impounded water found vent. The destruction under the tracks of the Toledo & Ohio Central Railroad, located on the levee at Sandusky St., was almost complete. The great 36-in. main of the Columbus water works, which feeds the West Side, was here destroyed. This put the water supply of the entire city out

of commission for almost an entire day until the water subsided far enough so that a valve could be reached which would stop the loss through this break.

The high velocities that were created at the subways, where heads as high as 10 and 12 ft. were noted between the upstream and downstream water lines, did great damage both above and especially below them. Almost all the houses in their immediate neighborhood were destroyed and if not swept completely away they were overturned, piled up and practically ruined.

The destruction in the Toledo & Ohio Central Railroad yards at Columbus, by breaks in the levee just north of it, was very great. Most of the damage was caused by the height of levee which, when overtopped and broken, caused high velocities in the vicinity.

In Columbus, the Baltimore & Ohio Railroad track elevation formed an almost complete impounding reservoir, through which there were only four subway outlets. The one at Sullivant Ave., caused great destruction, a pit being excavated to a depth of 24 ft. below the street level. (Fig. 4.) The abutments of this subway were built of 2 ft. dimension stone, and they held together well. The entire abutments, however, were undermined, a large portion of one being carried clear across Sullivant Ave.

Fig. 4. Sullivant Ave., Subway Under Railroad After the Flood.

Many people were drowned at this point because of the rapid current. Houses from above the subways were sucked into it and their inhabitants drawn down into the rushing water, without hope of escape. A field of bowlders many acres in extent covered the dis-

trict below this subway to a depth of 3 or 4 ft., and nearly a hundred houses were swept away.

The erosive effects on different types of surfaces were noticed by Prof. C. E. Sherman of the Ohio State University immediately after the flood. Sod appeared to withstand erosion much better than macadam, but it was observed that when the sod did begin to give way through the erosion, it was destroyed in long furrows, giving the appearance of plowed ground. The resisting power of sod against erosion has been well-known, but the effects observed in Columbus will renew confidence in sodded slopes.

PROJECTS FOR RELIEF.

In considering projects for relief, it was, of course, important to decide upon the factors of safety which should be introduced. From a review of all the large storms in this country, there can be no doubt that the storm which covered the Ohio Valley in March, 1913, was one of the very great storms; nevertheless, it is easy to see that all of the factors producing large storms were not present. If the heaviest precipitation had occurred entirely within the Ohio Basin, or within any one of the different tributaries, or if the precipitation had occurred with a great depth of snow on frozen ground, the run-off would have been greater and more sudden than was actually the case.

On one part of the Scioto watershed there was in operation a large natural restraining reservoir, which caused the water from the upper watershed to be detained, and which prevented additions to the crest of the flood, and further, three inches of the total rainfall occurred after the crest of the flood had passed Columbus. Under these circumstances, we must admit that the flood of March, 1913, might be materially exceeded in the future. It was a difficult question to decide on what scale of protection projects for relief should be based. It was finally decided to adopt at Columbus at least two scales of protection, in order that all might fully understand the relative costs involved.

FACTORS OF SAFETY.

The results can be best shown upon the well-known chart made by Mr. Emil Kuichling for the Deep Waterways Commission some ten or twelve years ago. (Fig. 5.) While all of the recent great storms are not upon this chart, the more important ones here considered are noticed, so that we may visualize them as a basis for reasoning, in the light of the great storm which just occurred. It must be remembered that in works for relief we have not only to deal with great floods, but great floods which may be accompanied by ice gorges, accidents to bridges, accumulations of débris and other difficulties which make it imperative to extend our factors of safety much more than would be necessary if they were predicated on flood heights

alone. For this reason, at Columbus, bridge clearance was generally made 6 ft. above the adopted high water mark and levees were carried ten to twelve feet above this mark everywhere except at a few of the more important bridge crossings, where they were 6 ft. above. This, with some emergency work, would give a factor of safety of about one half more than the actual flood upon which the relative projects were predicated, thus works for protection against a flood of

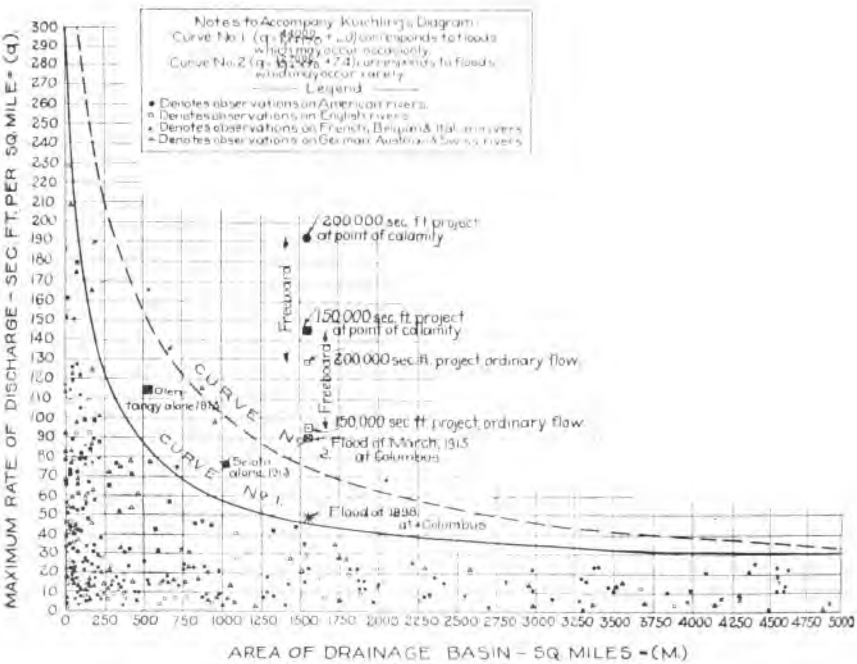

Fig. 5. Rate of Maximum Flood Discharge.

150,000 sec.-ft. would actually have a capacity of nearly 225,000 sec.-ft. before a great calamity would occur, and likewise works for a flood of 200,000 sec.-ft. would have really about 300,000 sec.-ft. capacity.

The very great cost of works for protection, in proportion to the value of the property to be protected in Columbus, seemed to point to the necessity of adopting the lower class of projects as being reasonably complete and stable. It may be suggested that an economic comparison, based on the value of the property to be protected, would be illuminating. This might be useful had we only to consider property and financial value, but in problems like those at Columbus and Dayton, where thousands of people are living at lower levels than the necessary flood heights, it is obvious that reasoning, based on financial

considerations alone, will not suffice. Human life and suffering cannot easily be capitalized.

RESERVOIR PROJECTS.

Very early in the investigation it was found that large reservoir storage was possible both above Columbus and Dayton. Above Columbus the watershed of the Olentangy and Scioto rivers is a gently rolling one in its upper courses. Some parts of the upper Scioto are indeed quite level and formerly comprised a large marsh. For about 25 miles above Columbus, however, both rivers flow parallel through rock gorges from 500 to 1,500 ft. in width and from 60 to 100 ft. in depth. There are few tributaries entering the rivers in this reach, and a number of good sites for high dams can be found. Those which were the most available were located and it was estimated that about two inches of rainfall on the watersheds above them could be stored in reservoirs whose cost would not be excessive. Other reservoir sites than these were observed to be practicable, but with greatly increased cost due to the better value of the agricultural lands utilized. It will be observed that the March, 1913, rainfall of 9.34 ins. would be nearly five times the available economical storage. The small proportional storage led to some embarrassments. Speaking generally, however, it was fortunate that such good sites were found so near to the points to be selected, and upon lands which were either not farmed or were not of high value.

Delaware, as well as Columbus, would be materially benefited by a storage dam immediately above it, and it was clear from the studies made that the more numerous the communities to be protected, the more advantageous general storage becomes.

It is interesting, as bearing on the general proposition of reservoirs for flood relief, to note how the different conditions in Columbus and Dayton pointed toward different solutions of the proposition. For Columbus, projects with a fraction of the flood stored in reservoirs, combined with channel improvement, were found to be not materially cheaper than a channel-improved project alone, but in Dayton the Morgan Engineering Company has found that supplementary channel projects are so expensive, and available reservoir sites so much nearer the full flood capacity required, that everything now seems to point to reservoirs as the proper solution there, while channel improvement is the proper solution for Columbus, considered by itself.

In the Dayton watershed, the reservoirs approach very much nearer in capacity to the run-off to be provided for than is the case in the Columbus watershed. There is one reservoir proposed on the Stillwater River above Dayton which will hold over 12 ins. of rainfall from the watershed above it, and another, on the Mad River, has a capacity for 6 ins. of rainfall on the watershed above it, and there are

three others with a goodly capacity for a proportion of the rainfalls which they might receive. This reduces some of the difficulties of reservoir projects, because where reservoirs have only a fraction of the capacity of the probable rainfall they must be constructed so that large quantities can pass over their spillways, and thereby secondary flood waves may be created which are often but little less in height than the original flood wave would be.

It is hard to realize the magnitude of these reservoirs for full flow. In the March, 1913, flood the Dayton reservoirs would hold 1,500,000 acre-ft., and the Columbus reservoirs 750,000 acre-ft. To safely store this vast amount of water in close proximity to the city is indeed a problem. It is theoretically possible at Dayton to take care of almost all the rainfall which occurred March last, leaving about 50,000 sec.-ft. to flow through the present city channel, which would not tax its capacity.

Another fact which works in favor of the reservoir solution at Dayton is that the dams there can be largely constructed of earth, while at Columbus, owing to contracted sites, and the necessity for large spillways, the dams must of necessity be of concrete.

DETAINING TYPE OF DAMS.

As a typical example, let us take the dam on the Scioto River proposed for the protection of Columbus, known as the "Dublin dam." All of the proposed Columbus dams are to be of the "detaining type"; that is to say, constructed with large openings in their bases which will permit light floods to pass freely through them without detention while larger floods will be partially detained, and great floods more largely detained. It is obvious that the greater portion of the lands above this type of dam would not be flooded except when a quite large flood occurred, so that, with reasonable precautions, they could usually be cultivated. It is not, therefore, necessary to devote such lands entirely to reservoir purposes, but it is evidently necessary that the land should be owned and controlled for the purpose for which it is designed. *"Calamity reservoirs,"* as we may properly call them, should not be filled for any other purpose than to detain great and destructive floods, unless a certain definitely defined proportion of them be conserved for other purposes and excluded from consideration for flood protection purposes. Whether this is safe and certain under our American municipal conditions is an open question.

An interesting set of curves has been worked out for the Columbus conditions, which show the theoretical effect of different amounts of storage in flood protection; first, where under control by gate regulation; and second, by automatic detention. Theoretically, it seems possible, with any given amount of storage fractionally less than the

full flow, to reduce the crest of flood waves by the amount of such fractional storage, but to accomplish this practically, the operator would have to have a foreknowledge of just where on the rising flood to begin to store.

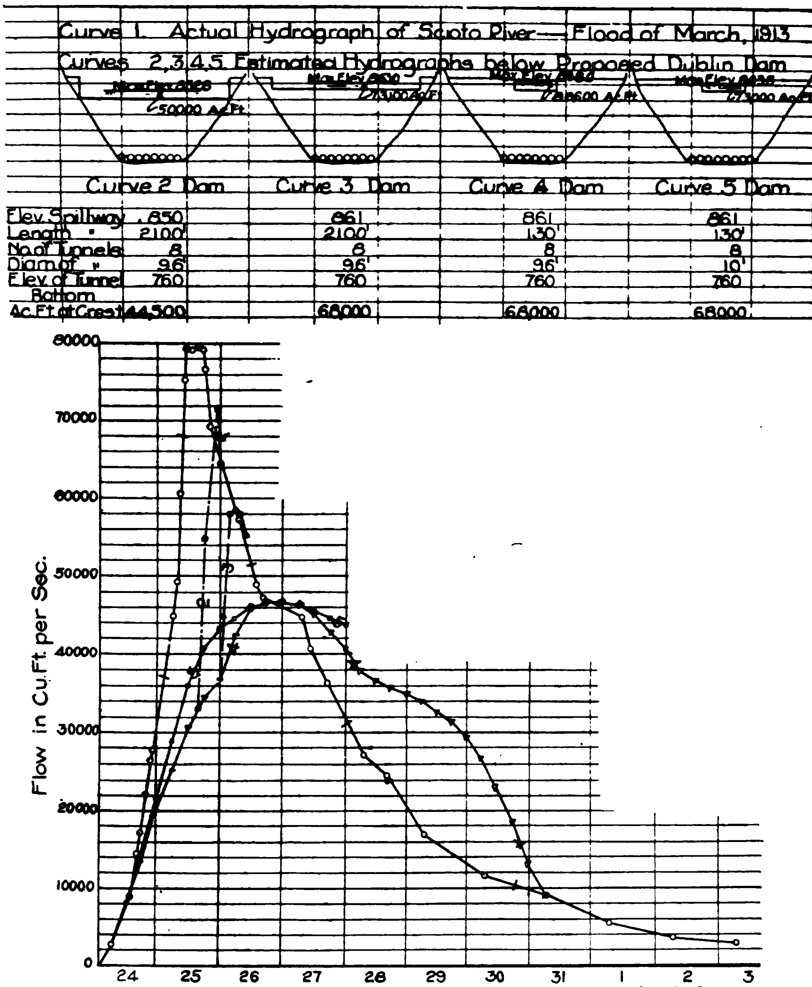

Fig. 6. Hydrographs of Scioto River Below Proposed Dublin Dam Showing Effect of Various Dams and Spillways in Reducing Flood of March, 1913.

With reservoirs practically effective and which automatically operate, that is to say, of the detaining type, designs must be made for a certain type of flood graph, and for other types of flood graphs,

may not be so efficient. At Columbus, studies were made upon the actual flood input and output of such reservoirs as were possible on the Columbus watershed. Nearly all of the reservoirs, both at Columbus and at Dayton, would store quite as much water in the upper ten or fifteen feet as in the lower sixty or seventy feet. It becomes important in so-called fractional storage, under these conditions, to know what size and height of spillway and size of sluiceway is best, in order to get the best results in effectively cutting off the crest of any theoretical flood wave. Under the particular conditions of the Dublin dam, for instance, it developed that a deep and short spillway was most effective. In the diagram (Fig. 6), the different curves show important differences in efficiency due to the varying height and length of spillway and amount of opening.

A further diagram was constructed to show the final detention efficiencies obtained by the Dublin and Delaware dams above Columbus, which together were finally counted upon to detain safely 50,000 sec.-ft. of flood flow. Economically, it seemed undesirable to introduce any more storage than this for the protection of Columbus alone.

The adoption of the detaining type of reservoirs at Columbus was largely due to the desire to avoid reliance on human vigilance, thus all operated types of flood relief were excluded from consideration as a matter of principle. In works which are only to be used once in twenty-five or fifty years, it does not seem prudent to rely upon human vigilance. Much cost might be saved if certain types of control gates and emergency dams could be introduced in works in the city and for channel improvement, but all of these were discarded, under the circumstances, as being unsafe and improper of application to a problem of this kind.

It is also to be questioned if great outlet gates are practicable in emergency dams, or so-called "calamity reservoirs." Such gates must necessarily be very large, exceeding in size most of those now used, and operated by power, as they must be, and at infrequent intervals, their introduction is questionable.

THE RECOMMENDED PROJECT AT COLUMBUS.

The recommended project at Dayton has not yet been finally worked out. At Columbus, that recommended might be described as a "channel straightening project." The West Side, consisting of a long, narrow, populated area crossing the valley like a dam, is to be crossed by a proposed new channel about 6,000 ft long, 900 ft. wide at the top, and 600 ft wide at the bottom. Above and below this new channel the river is to be confined by levees, converging to the channel on the upstream, and diverging from it on the downstream side, so that the flood may gather itself together for its flow through the channel, then spread itself out again upon the flood plain below

the city. A mean velocity of 8 ft. per sec. was considered the highest desirable within the artificial channel, and 10 ft. mean velocity was considered the limit for bridge openings.

The cost of the recommended project was over $11,300,000, of which about $8,500,000 would be represented by the city's outlay and the balance by the railroads and other interests.

The expensive part of such a project is comparatively short at Columbus, which fact accounts for the favorable comparison of channel-straightening projects as against reservoir projects. In Dayton the reverse is the case. Any channel project there must be several miles in length through well-populated areas. In Columbus, the character of the houses in the district where the improvements would be made was such that it was found to be more economical to provide width of channel than great depth. Three fine reinforced concrete arch bridges are proposed to take the place of five or six old steel bridges existing on the Bend. Two railroad bridges may be dispensed with under the new plan, and only two new railroad bridges will have to be provided. Superior access is given to the city from the West Side, and the old abandoned river channel, amounting to about 65 acres, might be filled, if desired. About seven hundred and fifty houses would have to be taken down or removed, most of them being wooden buildings of the cheaper grade, although one or two good churches and some good store buildings are included.

The city of Columbus has already voted upon a proposition to issue eight and a half million dollars' worth of bonds to initiate this improvement, and while considerably over a majority were in favor of the proposition, the law in Ohio requires a two-thirds majority, which was not attained. People from the flooded district voted for the proposition almost to a man, but other members of the community residing on higher ground did not appear to relish the proposition to pay for the work with a blanket bond issue, the proceeds of which would be very largely used in one section and that the least valuable in the city; consequently enough votes were cast against the measure to defeat it.

It is probable that during the coming winter measures will be introduced in the Ohio legislature looking toward the formation of flood relief districts, by means of which Dayton can combine with its adjacent cities and apportion the benefits more properly and justly than would be otherwise the case. Such laws would permit Columbus to consider more carefully the question of reservoirs in combination with Delaware and other smaller cities which might be benefited thereby. In any event, it would appear that a law which would provide for the special assessment of at least a portion of the benefits ought to be passed so that a more equitable adjustment of the costs upon the property benefited within the city could be made.

REMODELED UNDERDRAIN SYSTEM FOR A MECHANICAL FILTER PLANT.

BY JESSE M. WORTHEN, M. D.*

Beginning in April, 1912, the underdrain system of the filters, began to give trouble. The strainers and laterals became incrusted with a lime deposit. Cleaning the strainers failed to relieve permanently the condition, as in a few weeks they were incrusted as badly as before cleaning.

There were three styles of strainers in use, first the mushroom strainer of the New York Continental Jewell Filtration Company, second a small cast bronze strainer with small holes drilled in same, and third a small gauze strainer. The last two were made by the Simplex Valve & Meter Company.

The incrustation seemed to be a calcium carbonate formation, although no analysis was made of it. The openings in the strainers were filled completely. A heavy deposit was found on the inside as well as on the outside of the strainers, and also on the inside of the laterals.

The raw water is taken from an impounding reservoir of 2,500 acres. The land flooded by the water of the impounding reservoir was not cleaned or stripped. It was composed partly of salt marsh land. The capacity of the impounding reservoir is 3,000,000,000 gallons.

Average analyses of the raw and filtered water in parts per million are as follows:

	Raw	Filtered
Chlorine	17.0	17.0
Color	150.0	15.0
Turbidity	3.0	0.0
Alkalinity (To erythrosine)	10.0	12.0
Alkalinity (To phenolphthalein)	0.0	0.0
Hardness (Soap test)	22.1	36.4
CO_2	7.3	1.1

The treatment of the raw water consists of the addition of 2 grains of sulphate of alumina as the water leaves the low lift pumps on the way to the sedimentation basins. There are two basins with a capacity of 5,000,000 gallons each. The water is pumped to basin

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No. 1, from which it flows through a 24 inch pipe into basin No. 2. As the water leaves basin No. 1, 0.25 grains per gallon of sulphate of alumina are added as a recoagulant. From basin No. 2 it flows by gravity to the filters. The period of sedimentation is about 20 hours in each basin, or a total period of sedimentation of 40 hours.

The filter plant consists of twelve wooden units, with a capacity of 500,000 gallons each in 24 hours. To bring up the alkalinity in the filtered water, 0.75 grains per gallon of hydrated lime are added. The lime solution is added to the filtered water in the flume which carries the filtered water to the clear water basin of 2,000,000 gallons capacity.

On finding the strainers incrusted two methods of cleaning were tried. One was to take the strainers out and clean by hand, the other was to immerse the strainers in a nitric acid solution. In thirty days the strainers were again incrusted. It came to a point of finding a substitute for the strainers or a new system of underdrains.

After much study, and consultation with the American Pipe and Construction Company, the following scheme was tried. It has proven a success.

All the lateral system was removed from the filters. New lateral pipes were capped and drilled with quarter inch holes spaced six inches center to center. These were placed in the filters with the holes turned downward. Then a system of stringers of wood was put in place and held by copper nails. In the bottom and around the laterals six inches of ¾ to 1 inch gravel was placed. On this four inches of large pea gravel, then two inches of small pea gravel were placed. Over this was placed copper screening, 100 meshes to the square inch, nailed with copper nails passing through copper washers. The filters were filled to the required depth with sand. See Fig. 1 and Fig. 2 for full details of the new underdrain system.

To the present time, February 15, 1914, the underdrain system has worked to perfection.

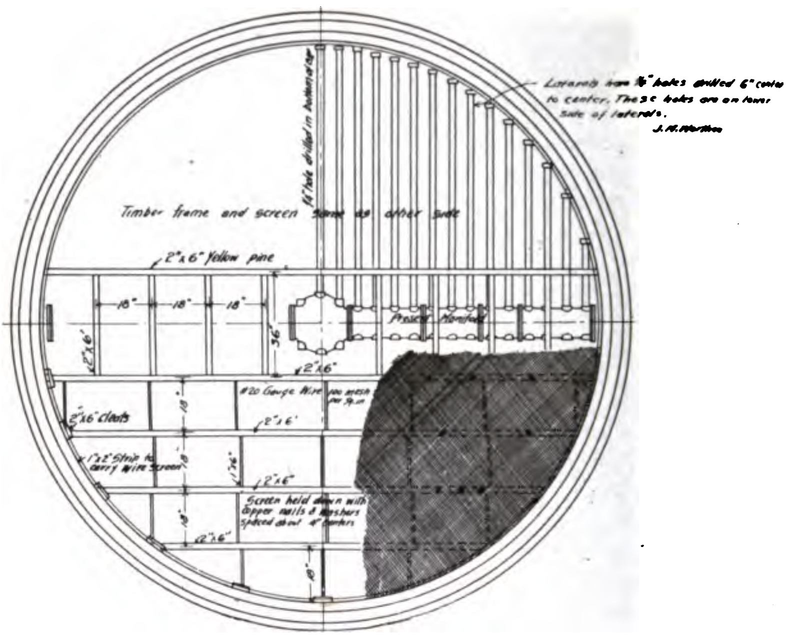

Fig. 1. Plan of Framing for Screen.

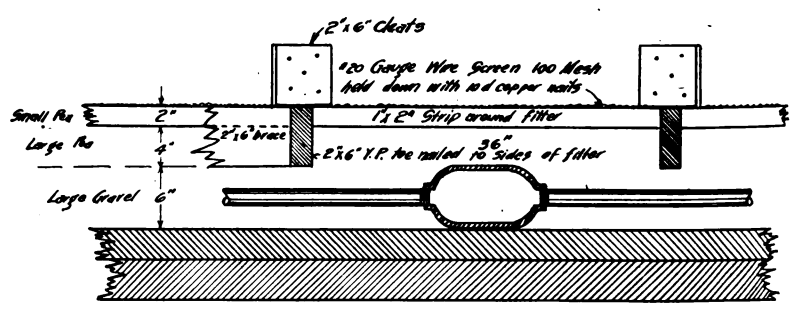

Fig. 2. Cross Section of Framing for Screen.

THE RELATION OF "OUT-OF-POCKET COST" TO RATE MAKING.

BY MORRIS KNOWLES* AND MAURICE R. SCHARFF.**

Within the last few months, we have all been greatly interested in the numerous interesting papers and reports that have been published, and in the resulting discussions and controversies, with regard to the subjects of valuation, depreciation, rate of return, etc. These meetings of minds are of the greatest value, and promise in the near future a substantial agreement on some of these perplexing problems affecting the determination of a fair gross income for a public utility corporation. But we should not forget that the determination of such a gross income is only a preliminary step to its distribution among consumers by means of just and equitable rates, and we can well afford to take up simultaneously some of the unsettled points in the construction of rate schedules. It is our desire in this paper to call attention to this fact, and to discuss briefly the relation to rate making of one element, which we have called for lack of a better name, the "Out-of-Pocket Cost". As of especial interest to this audience, we shall refer to water rates throughout, although a similar line of reasoning is equally applicable to some other public utilities, and to some extent applicable to all.

Owing to the difficulty of recognizing inequalities in rate schedules and to the relatively satisfactory results attained by the customary unscientific methods of framing them, there has not been so much study given to this portion of the general problem of valuation and rate making; yet, all who give the matter thought, must recognize it as one of the most important and complex portions of that problem. Indeed, so complex is it, involving as it does many yet unanswered questions of accounting and of commercial and economic policy, and touching at many points the human element, which cannot be mathematically estimated, it may well be said to be incapable of exact solution.

The perfect system of rates cannot be determined *a priori*; it must come, rather as the result of evolution, of gradual improvement as the outcome of human experience. It is, however, possible, with

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an understanding of such principles as have already been worked out and using the best judgment we can bring to bear to attain results far preferable to those based on the belief that it is useless to compute rates at all. For the former method is bound to reach by experience a closer and closer approximation to the truth; while the latter can never advance a single step.

Now in spite of the complexities and uncertainties in the computation of reasonable rates, their definition is fairly well agreed upon. Reasonable rates have been defined as

> "Such as will, in an efficiently operated utility, yield sufficient revenue to permit satisfactory service, and to pay in addition to operating and maintenance expenses and depreciation a fair return upon the fair value of the property used and useful for the public service—all without discrimination and with due regard for the public interest."

Fortunately, we are not concerned at this time with the meaning of satisfactory service, reasonable expenses, depreciation, fair return, or fair value. We may, therefore, assume them all satisfactorily settled, and the proper gross income determined, reducing our definition to lower terms in somewhat the following form:

> "Reasonable rates are such as will assess the proper gross income upon consumers without discrimination, and with due regard for the public interest."

With these preliminary remarks, let us consider the meaning of the terms "without discrimination" and "with due regard for the public interest."

"Discrimination" is defined in the Standard Dictionary as "differential treatment", and the literal application of this definition would seem to require that rates "without discrimination" should be based strictly on cost of service, without differential treatment according to amount of use, hours of use, kind of use or any other distinction. It has been repeatedly decided, however, that this term does not preclude the classification of consumers and differential treatment of the classes, on any reasonable basis. Some extension must therefore be given to the literal meaning of the term, in order to make it workable, and while it has not been clearly formulated by the authorities, the "rule of reason" would appear to require that discrimination be defined as "differential treatment, except in so far as public interest requires."

Pursuing this line of thought a step further, we have come to the conclusion that there are but two grounds on which "public interest" may require differential treatment of consumers.

First,—in order to secure some contribution to the public welfare—a method of indirect taxation of those against whom the differential treatment militates.

Second,—in order to lower the cost to other consumers by retaining or securing custom which would otherwise be lost.

Some will no doubt contend that "with due regard for the public interest" has reference to the general welfare in such a way as to justify the lowering of rates on certain necessities to certain consumers, even to below cost, for the sake of extending the benefit connected with their use, or in order to encourage business, or for some similar reason. The argument appears to be that, while such steps have the effect of saddling a disproportionate share of the expense upon other services, or upon other consumers, it is nevertheless justifiable as a kind of indirect tax, and as in the public interest. Thus it may be held that freight rates on coal should be low, so as to permit the cheap movement of fuel, and to prevent the localization of industry near the coal fields, with resultant evil social effects. Again, it is argued that water should be supplied free to charitable institutions and to new factories or industries, on account of the public interest therein; and that water should be supplied to small consumers at excessively low rates, so as to favor liberal use and promote public health. But we see no force in these arguments as applied to rate making. Indirect taxation is a useful part of our system of raising governmental revenue, and on account of the relative ease of administration and collection, may well be retained until equitable methods of direct taxation, such as income taxes, are more thoroughly worked out. But we are inclined to believe that its use should be confined to raising public revenue and that it should never take the place of actual governmental appropriation as a method of subsidizing any industry or service, no matter how desirable the encouragement of the latter is from the point of view of public welfare. We believe that President Wilson is deserving of the highest commendation for refusing to compromise with a principle in order to carry out an ill-considered plank of the Baltimore platform, and for demanding of Congress that, if coastwise shipping is to be subsidized, it be done in the open and above board by congressional appropriation and not by the underhanded method of remitting tolls for passage through the Panama Canal.

There remains, then, only the second basis which seems to us proper as a reason for differential treatment of consumers—in order to lower the cost to other consumers by retaining custom which would otherwise be lost. How this works out may be very readily explained. Assume a small waterworks with a gross income, which must be collected when it is supplying 1,000,000 gallons per day, of $35,000. Now suppose one large consumer, using 100,000 gallons per day and paying $3500 per year should find that he could secure water elsewhere at a cost of $2500 per year, and should disconnect from the mains. The amount supplied would drop to 900,000 gallons per day; but

interest, depreciation and maintenance would remain practically the same; it would still be necessary to have the same number of engineers and firemen; and the only saving would be a small amount on fuel, alum, hypochlorite, oil and waste, etc., which would certainly not be in excess of $1000 per year, and would probably be a great deal less. So that the gross income to be raised might be reduced to say $34,000., all of which would have to be raised from other consumers. Now if all other conditions remained the same, and the rate for the large consumer were reduced so as to just hold his custom, when paying $2500. per year, the total gross income would still be $35,000. and the portion to be raised from consumers other than the large one would be $32,500, or $1500, less than in the other case. Their rates could, of course, be correspondingly lower than would be necessary if the large consumer were lost. The advantage of such an arrangement to all of the consumers is obvious, and such differential treatment if necessary to secure this advantage, would not only not constitute discrimination as we have defined it, but would appear to be a plain duty of the water works as a public utility.

In brief, it is to the advantage of all consumers that large, long hour, high load-factor consumers be retained. Differential treatment of them does not constitute discrimination, so long as it will result in advantage and saving to other consumers. Such concessions in rates, however, must not be greater than actually necessary to meet the competition of other sources of supply. And in any case, they must not be so great as to increase instead of decrease the income to be collected from other consumers. Thus in the case cited above, if it were possible to get the business at $2500., any rate less than that sum would constitute discrimination. While if it were really necessary in order to meet competition, any rate greater than $1000. per year would effect some saving for other consumers, and would be justifiable. A rate less than $1000., however would make the amount to be collected from other consumers greater than if the large consumer ceased entirely to take service. This would certainly be discrimination under our definition.

The lower limit ($1,000. in the above case) below which rate concessions cannot be made, even if necessary to secure business, without constituting discrimination, and which represents the actual expense which would be saved if the consumer in question were disconnected, we have called the "Out-of-Pocket Cost". We have found its estimation of value, not only for determining the lower limit of the proper total annual charge, but also practically, in framing rate schedules.

The cost of supplying water may be said to be made up in the first analysis, of the Cost of Readiness to Serve, or costs which result from providing the plant and maintaining it ready to serve, and

Output Costs, which result from operating the plant, and vary more or less closely with the amount of water supplied.

The Cost of Readiness to Serve may be further sub-divided into Capacity Cost, of which interest is the best example, which varies directly as the capacity of the plant, and may equitably be distributed to consumers in proportion to their demands, which require this capacity; and the Service Cost, which varies with the number of services, and may equitably be assessed equally upon all services. Meter reading, billing and collecting are typical of this.

Similarily, the Output Cost may be divided into two parts, the Out of Pocket Cost, defined as above, and including all expenses for materials and labor used in small units and varying closely with the consumption; such as coal and alum; and the Remaining Output Cost, which includes expenses occurring in large units and varying somewhat with, but not directly as the consumption. Typical of these are the wages of pumping engineers and firemen.

In computing a rate schedule, it seems reasonable to divide the gross income into these four parts, and to combine the Demand Charge, equal to the demand of the consumer (as measured by the size of meter) over the total demand, times the total Demand Cost, and the Consumer Charge, equal to the Consumer Cost, divided by the number of consumers, in a minimum charge. If no differential treatment were necessary, all the remaining costs would then be assessed by a uniform meter rate, obtained by dividing the total Output Cost by the total annual metered sale of water. Differential treatment, in order to secure the business of favorable consumers who would not take water under these circumstances, might then be effected by relieving such consumers either of a portion or all of the Minimum Charge, or of a portion or all of the Remaining Output Cost, or of a portion or all of both. But it happens that the Minimum Charge so calculated, is ordinarily a small part of the cost of water to the large, long hour, high load-factor consumer to whom concessions must be made. Moreover, it would unduly complicate rate schedule computations to attempt to divide the necessary concession between the Minimum Charge and the Meter Charge. And we have not, in our experience, met with any such case in which the possible concession in the meter rate was not sufficient or more than sufficient to get the business.

Conceivably it might be possible to classify consumers into groups by quantity used, location, or whatever reasonable basis made differential treatment necessary, determining for each group the cost of an alternative supply to which they would turn if concession were not made, and fixing in this way the extent to which it would be necessary and proper to relieve each group of a portion of the charge. But ordinarily this would be difficult or impossible, and it will usually be preferable to group all such large consumers, whose loss is threatened,

TABLE NO. 1

ALLOCATION OF ESTIMATED TOTAL REVENUE

Item	Total	Percent Division		Division		Percent Division Readiness to Serve		Division Readiness to Serve		Percent Division Output		Division Output		Apportionment			
		Readiness to Serve	Output	Readiness to Serve	Output	Capacity	Services	Capacity	Services	Out of Pocket	Remaining Output	Out of Pocket	Remaining Output	Capacity	Services	Out of Pocket	Remaining Output
Advertising	$ 200.00	100		$ 200.00	$	100		$ 200.00	$			$	$	$ 200.00	$	$	$
Insurance	150.00	100		150.00		100		150.00						150.00			
Interest	29190.00	100		29190.00		100		29190.00						29190.00			
Supplies	850.00	28	72	240.00	610.00	46	54	110.00	130.00		100		610.00	110.00	130.00		610.00
Legal	450.00	100		450.00		100		450.00						450.00			
Light	60.00	100		60.00		100		60.00						60.00			
Meetings	225.00	100		225.00		100		225.00						225.00			
Patrolling Res'v's	600.00	100		600.00		100		600.00						600.00			
Pumping																	
Engineer	800.00		100		800.00						100		800.00				800.00
Coal	2400.00		100		2400.00					100		2400.00				2400.00	
Incidentals	300.00		100		300.00					10	90	270.00	30.00			270.00	30.00
Power	1000.00		100		1000.00					100		1000.00				1000.00	
Repairs																	
General	200.00	100		200.00		20	80	40.00	160.00					40.00	160.00		
Reservoirs	200.00	100		200.00		100		200.00						200.00			
Pumps	3000.00		100		3000.00					20	80	600.00	2400.00			600.00	2400.00
Filters	700.00		100		700.00					20	80	140.00	560.00			140.00	560.00
Distribution	3000.00	50	50	1500.00	1500.00	100		1500.00		10	90	150.00	1350.00	1500.00		150.00	1350.00
Rent	300.00	100		300.00		50	50	150.00	150.00					150.00	150.00		
Salaries																	
General Man.	2500.00	100		2500.00		10	90	250.00	2250.00					250.00	2250.00		
Oper. Man.	3500.00	50	50	1750.00	1750.00	80	20	1400.00	350.00		100		1750.00	1400.00	350.00		1750.00
Telephone and Telegraph	200.00	100		200.00		50	50	100.00	100.00					100.00	100.00		
Traveling	300.00	100		300.00		100		300.00						300.00			
Teams	400.00	50	50	200.00	200.00	100		200.00		10	90	20.00	180.00	200.00		20.00	180.00
Taxes	2100.00	100		2100.00		100		2100.00						2100.00			
Analyses	150.00	50	50	75.00	75.00	100		75.00			100		75.00	75.00			75.00
Bleach	35.00		100		35.00					100		35.00				35.00	
Filter Operation																	
Labor	500.00		100		500.00						100		500.00				500.00
Alum	500.00		100		500.00					100		500.00				500.00	
Incidentals	200.00		100		200.00					50	50	100.00	100.00			100.00	100.00
Depreciation																	
Reservoirs	3965.00	100		3965.00		100		3965.00						3965.00			
Pumping Sta.	1309.00	30	70	392.70	916.30	100		392.70		14	86	130.90	785.40	392.70		130.90	785.40
Filter	633.00	50	50	316.50	316.50	100		316.50		20	80	63.30	253.20	316.50		63.30	253.20
Distribution	2228.00	90	10	2005.20	222.80	100		2005.20			100		222.80	2005.20			222.80
General	325.00	100		325.00		50	50	162.50	162.50					162.50	162.50		
Reading Meters	500.00	100					100		500.00						500.00		
Total	$62970.00													$44141.90	$ 3802.50	$5409.20	$9616.40

into one group, determining the extent to which it will be necessary to relieve the consumer most favorably situated with respect to an alternative supply and either apply his rate to all large consumers, or if he is the largest (as is likely), taper the rate to this in uniform steps from the smaller consumers' rate.

These computations cannot, of course, be established as theoretically accurate, but improved accounting and good judgment will lead to results in which confidence may be had as closely approximating the ideal. As an example of the method, we present below in skeleton, the computations involved in its application to a rate schedule prepared for a small water company in the East.

The fair normal gross income for the period to which the rates were to apply was first determined as $62,970.00. This was then distributed in the manner shown in Table I.

The fair fire protection payment to be made by the city was then computed as $14,566.00 (the method need not concern us at this time.) Deducting this from the total Capacity Cost, we have $29,576.00 left to assess on consumers as Demand Charges.

The estimated number of meters and the assumed demand of each having been agreed upon, the Demand Charge for each size of meter was then computed as shown in Table II.

TABLE II.

COMPUTATION OF DEMAND CHARGES

Size of Meter	Number of Meters	Demand per Meter c. f. p. m.	Total Demand	Demand Charge per Meter
5/8", 1 spigot	500	1	500	$4.00
5/8"	1909	2	3818	8.00
3/4"	220	4	880	15.90
1 "	109	8	872	31.80
1½"	1	12	12	47.80
2 "	1	20	20	80.00
3 "	8	40	320	160.00
4 "	4	80	320	320.00
6 "	3	120	360	480.00
8 "	2	160	320	640.00
Total	2757		7422	

The Service Charge was then computed by dividing $3802., the total Service Cost, by the total assumed number of meters, and was equal to $1.40.

The total annual metered consumption was then estimated at 452,500,000 gallons, of which 270,000,000 gallons would be taken by a single large industry—the one consumer, if any, to whom concession would have to be made. Dividing the total Output Cost by the total consumption, we arrive at $0.033 per 1000 gallons as the average

meter rate at which all water would be sold if no differential treatment were necessary. Dividing the Out of Pocket cost by the total consumption, we have $0.012 per 1000 gallons, as the Out of Pocket Meter Charge, or the lower extreme to which the meter rate of the large consumer could properly be reduced, if the maximum concession had to be made. And dividing the Remaining Output Cost by the consumption of all except the one large consumer, and adding the quotient, $0.053, to the Out of Pocket Meter Charge, $0.012, we get $0.065 per 1000 gallons as the meter rate which small consumers would have to pay if the maximum concession were made to the largest consumer.

In any particular case of this kind, the next step would be to determine to what extent concession would be necessary in order to retain the custom of the large consumer, and so to fix between these limits the rates for the several classes of service. It happened in this case that it was determined that there would be no danger of losing the large consumer even at the average meter rate, so that the latter was recommended for adoption. It was also considered advisable in this case to include in the Minimum Charge, for 5/8″ meter only, a charge, at the average meter rate, for 30,000 gallons per year, in order to forestall the criticism that metering would curtail the use of water by the poor to a point below the minimum requirements of hygiene. The resulting schedule of net charges, together with the gross rates made necessary in order to apply a 10% discount for prompt payment, and the rounded figures recommended for actual use, are shown in Table III.

TABLE III.

NET, GROSS, AND ROUNDED RATES COMPUTED AS ABOVE

Item	Size of Meter	Net Charge	Gross Charge	Rounded Rate
Minimum Charge*	5/8″, 1 spigot	$ 6.40	$ 7.10	$ 7.00
" " *	5/8″	10.40	11.60	12.00
" "	3/4″	17.30	19.20	20.00
" "	1 ″	33.20	36.90	40.00
" "	1 1/2″	49.20	54.70	55.00
" "	2 ″	81.40	90.40	90.00
" "	3 ″	161.40	179.30	180.00
" "	4 ″	321.40	357.10	360.00
" "	6 ″	481.40	534.90	540.00
" "	8 ″	641.40	712.70	720.00
Meter	....	.033	.037	.04

* Minimum Charge for 5/8″ meters only includes charge for 30,000 gallons of water per year.

THE IRON REMOVAL PLANT OF THE CHAMPAIGN AND URBANA WATER COMPANY.

BY ARTHUR N. TALBOT.*

Reference has been made in the Proceedings of the Illinois Water Supply Association to experimental work on the removal of iron from the drift well water supplied by the Champaign and Urbana Water Company†. This plant was practically completed at the time of the 1913 meeting of the Society. It was put into operation about July 1, 1913.

The Champaign and Urbana Water Company obtains its supply from wells 150 to 160 feet deep which draw their water from fine sand in the drift. This water contains about two parts of iron (Fe) per million. As pumped from the wells, the water holds about forty parts of carbon dioxide per million, and practically no dissolved oxygen. The aeration obtained as the water is discharged from the wells into the reservoir adds oxygen to an amount of about four parts per million. Considerable trouble has been found at various times with the growth of crenothrix in the mains and at other places, and the dripping of water gave a stain to porcelain and other material. The collection of sediment in mains at dead ends and in connected lines having little movement of water has been such as to give trouble when a current is formed by the opening of fire hydrants or by other large drafts of water and the sediment is stirred up and carried through the service pipes. The small amount of iron in the water would not be so troublesome, if it were distributed through the supply in the way it comes from the wells, but when a large amount of iron and the accompanying growths are concentrated at particular times and in special localities in the city the difficulties are emphasized. Under these circumstances the company decided to construct an iron removal plant along lines which followed the methods used in the experimental plant.

The process used involves aeration and filtration through a sand

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†Removal of Iron from a Drift Well Water; Proceedings of the Illinois Water Supply Association, 1911, 151. Further Tests on the Removal of Iron from Drift Well Water, Proceedings of the Illinois Water Supply Association, 1912, 229.

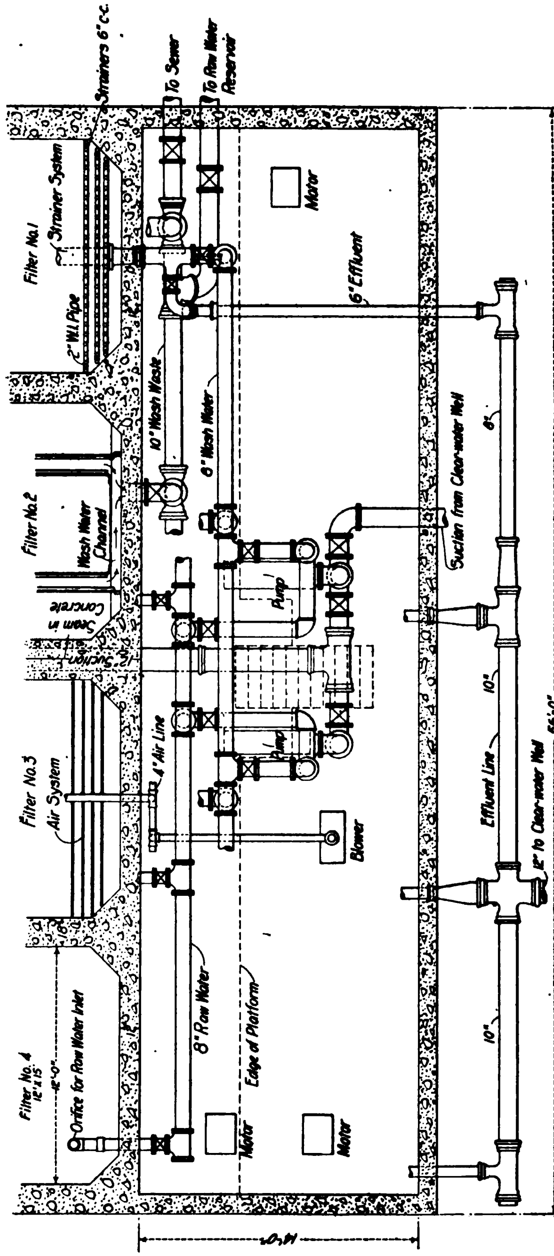


Fig. 1. Plan of Filter House.

filter, no coagulants being applied. The filter is much like the ordinary rapid sand filter except that coarser sand is used. Aside from removing iron from the water, among the special features of the plant are the method of measuring the raw water as it is discharged into the filter and the provision for variable level of water on the filter as a means of regulating the rate of flow through the filter.

The water is pumped from the wells into a receiving reservoir, which will be termed the raw water reservoir. Some aeration is obtained as the water is discharged into the reservoir. The water is pumped from the raw water reservoir upon the filters, and the filters discharge by gravity into the clear water reservoir. The two reservoirs named have been in use for many years.

The filter consists of four units of a nominal capacity of 500,000 gallons per 24 hours each, located in such a way that the number of units may be increased when needed. Fig. 1 shows the plan of the filter

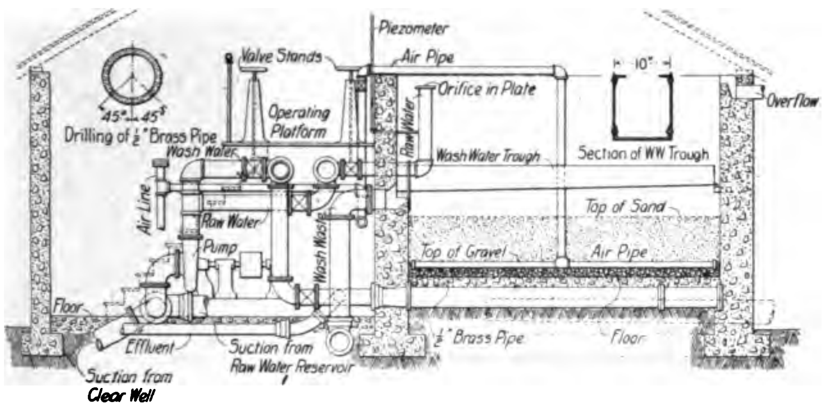


Fig. 2. Transverse Section Through Filter House.

and piping system. Fig. 2 is a transverse elevation. Each filter is 12 by 15 ft. in dimension, giving, with the space taken out at the corners, a cross-section of 178 sq. ft. The filter walls extend 9 ft. above the floor of the filter. The walls are built of concrete reinforced with steel rods, but their thickness is probably sufficient to resist the head of water without the reinforcement. The walls and floor are of 1-2-4 concrete and the foundations of 1-3-6 concrete. A fill of concrete made of one part cement, four parts of sand, and eight parts of cinders was placed under part of the floor. The foundation was first put in to the height of the middle of the depth of the floor. The walls were then built, the north two filters being constructed first and the south two filters next, the work in each case being completed in a working day. A thickness of floor was next put in up to the level of

the strainer system and after the strainer system was in place the floor was completed.

The strainer system and air system were furnished by the American Water Softener Company, of Philadelphia. The main collector is a cast-iron pipe 10 in. in diameter which reduces to 8 in. in the wall of the filter. This size gives a velocity of 5.7 feet per second with a wash of 1400 gallons per minute, equivalent to a rise of one vertical foot per minute. Two-inch tees are connected with this main collector and branch into 2-in. extra heavy wrought iron pipe in opposite directions. Hodkinson brass strainers with a throat opening .25 in. diameter are used. The spacing of the strainers is 6 in. center to center in each direction. Fig. 3 shows the loss of head through these

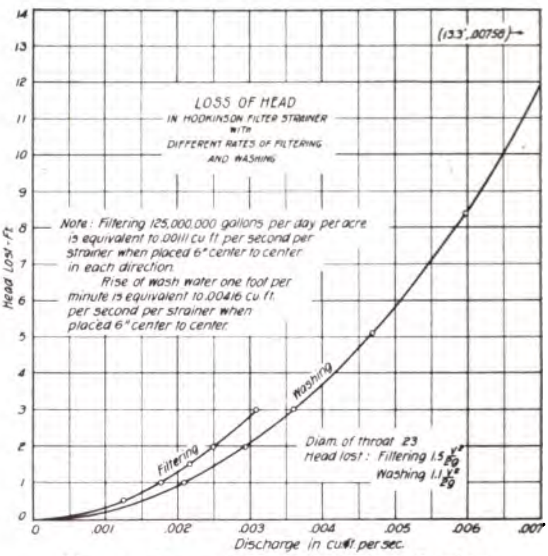


Fig. 3. Loss of Head in Filter Strainer.

strainers for a throat diameter of .23 in. for different rates of discharge.

A separate air system is used. The main is 4-in. wrought iron pipe which branches to 3 in. in two directions at the level of the gravel. ½-in brass tees and brass pipe feed from these branches. The holes are 1/16-in. diameter spaced 3 in. apart and placed at 45° points alternating on either side as shown in Fig. 2.

Each filter has two wash troughs which rest upon supports set into the end walls. The wash troughs have for the bottom a 10-in. 15-lb. steel channel, for the sides, ¼-in. steel plate, and have 2 × 1½-in. angles at the top set ½ in. below the edge of the plate. They are tied across by angle braces at five points in their length. The wash troughs

are 10 in. deep at the upper end and 14 in. deep at the lower end. These wash troughs have proved to be very satisfactory. The two wash troughs discharge into a channel placed along the ledge in the front wall of the filter, the wall being recessed 2 in. to give a larger cross-section, and the channel slopes both ways to an opening in the wall which connects with the 10-in. discharge line. This 10-in. drain connects with the sewer and there is a by-pass which permits a discharge into the raw water reservoir.

The raw water is discharged into the filter through an orifice in the vertical pipe, rising as a jet and dropping vertically to the surface of the water in the filter. The result is an increased aeration and the

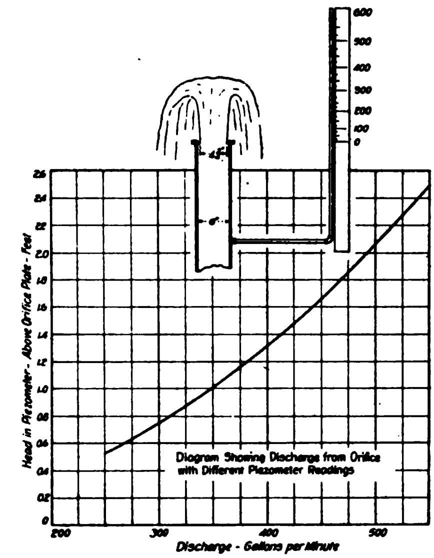


Fig. 4. Raw Water Orifice and Discharge Diagram.

water is practically saturated with oxygen when it reaches the filter. Fig. 4 shows the arrangement of the orifice. The vertical pipe (raw water discharge) has a connection with the glass tube. A scale along the tube properly graduated indicates the quantity of water which is being discharged, and the raw water valve is regulated until the desired rate of filtration is indicated on this scale. The apparatus forms a simple, accurate and sensitive method of determining the quantity of water discharged upon the filter. The figure also gives the discharge of the orifice at different heads.

The filter bed consists of about 30 in. of sand and 8 in. of gravel. The gravel ranges between ¼ and ½ in. The sand is washed bank sand from Williamsport, Indiana. After putting it in place in the filter, the sand was thoroughly washed several times by the usual filter

washing process, and the layers of fine particles which formed on the surface were then removed. Although this sand is not as uniform in size as is the filter sand which is usually specified, the saving in cost was so much that it was thought best to use it.

Two 8-in. American centrifugal pumps are used for pumping the raw water and wash water, being installed in such a way that either pump may be used for the raw water or the wash water. The pumps are run by 15 h. p. induction motors (with wound rotor), belt driven. Drum controllers and rheostats permit the speed of the pump to be changed 20% or more. This arrangement gives conditions of variable speed adequate for the range of discharge desired, and has proved a very satisfactory one. Care was taken in advance to estimate carefully the head pumped against and the speed necessary for the different rates of discharge. The blower was furnished by the Connersville Blower Company and has a capacity of 360 cu. ft. of air per minute.

The operating platform runs along the front of the filters at a height of about 8 ft. above the floor of the building. The various valves for the several filters occupy the same places relatively and are operated from this platform. All the principal valves of the piping system except those on the suction lines are also operated from this platform, as are the motors.

The east, north, and south walls of the filters form part of the enclosing building. The remaining walls of the building are brick covered with stucco.

As ordinarily operated, three filters have been in service and the normal amount of water used has been about 1,500,000 gallons per day. After a filter is washed the raw water discharge valve is set to give a discharge of, say, 350 gallons per minute. This is done when the water over the filter stands at a medium level, say 2 ft. below the overflow. The effluent valve is set so as to show the amount of lost head which experience tells is the usual amount just after the washing of the filters. If the head of water on the filter at starting is more than sufficient to produce the desired rate of filtration, the level of the water lowers, and if it is not sufficient to give the desired rate the level rises, until the level adjusts itself to give a filtration rate through the filter equal to the discharge upon the filter. As the filter clogs, the level of the water in the filter will rise to give the necessary additional head. A range of 4 ft. in the level of the water is available. A change in the effluent valve two or three times between periods of washing is sufficient to keep well within this range and to prevent overflow from the filter to the raw water reservoir. It has been found that the regulation of the rate of filtration is very easily managed, and the method has proved to be satisfactory. It has advantages over the use of a controller on the effluent pipe whose operation is hidden and uncertain,

and the amount of lost head is less with this device and the filter need not be raised to provide for such lost head. It also gives an accurate measurement of the water discharged upon each filter, which the ordinary controller does not do. The pumping arrangements work very smoothly and the piping system has proved convenient and satisfactory.

When the filters were first put in operation and while the sand was new, the filtration results were fully satisfactory. Only a trace of iron was found in the effluent. The runs were 30 hours or more and washing of the filter seemed to remove all sediment and restore the sand to its first condition, and no higher loss of head at starting was found than at the beginning of operation. After a month or six weeks of service, however, there was such an accumulation of sticky material in the filter bed and the sand grains had become so coated with this sticky substance that adequate washing over the whole area of a bed was impracticable, and the loss of head through the filter immediately after the bed had been washed became very high. The intervals between necessary washing were reduced to a few hours. While the filters were in this condition, large cracks would appear over the surface of the filter running well down into the sand, the appearance being much the same as that of mud cracks after drying. The effluent became poorer and poorer until at one time not half of the iron was removed by the process. To remedy this condition the sand from a filter was removed and given a thorough washing, and returned to its place in the filter. The result was that the operation of the filter became as satisfactory as when it was first put in operation. The other filters were then given the same treatment. As showing the condition of the sand layer, it may be said that pumping the sand through a centrifugal pump cleans it and separates the sticky material from the sand satisfactorily, and that the foreign matter will then float off and drain away. Further work is required to perfect the process of this occasional thorough washing of the sand. It is thought that the sand of a filter may be washed by running it through a centrifugal pump, and returned to its place directly, without using much more water than is required for the ordinary daily wash of the filter. The sand of the beds has been washed twice in eight months.

At present the occasional use of a fire hose in the bed in stirring and washing the sand grains has been found to be effective, and this will extend the length of the interval between the times when it will be necessary to scour the sand. The amount of water so used is not more than that required for the ordinary daily wash.

Changes have been made in the practice in the usual washing of the filter. The air wash is used as a means of stirring and is not generally put on while the wash water is being wasted. The bed is also stirred manually by means of a garden rake. Two washes are

given each day, as that has been found to give better results and not to increase the amount of wash water required.

During this time, experimental work has been carried on through the cooperation of the State Water Survey, with one or more of the filters, to learn if the application of chemicals to the water would lessen the difficulties in the washing of the filters. Suffice it to say that no advantage was found by the application of any of the chemicals used.

The clogging of the filters was the only difficulty which had been feared and now that this obstacle in the operation of the filter has been overcome the results are entirely satisfactory. The removal of iron from the water without the use of chemicals is found to be a very simple process. It seems probable that the same process is applicable to many of our drift well waters.

The entire work of constructing the filters was done by the water company's force and by day labor, no contracts being let. Mr. F. C. Amsbary, manager of the water works company, was in general charge of the work. Mr. Marquard, engineer of the water company, superintended the installation of the piping, pumping, and strainer systems and of the filter materials. Mr. G. C. Habermeyer made details of the plans and inspected the construction for the writer.

DISCUSSION.

F. C. Amsbary: (By letter) The success of our filter plant, which was designed and the construction superintended by Prof. Talbot, is unquestioned. On the average we are removing 85 to 90% of the iron and the product is very satisfactory. From a mechanical standpoint, we have experienced no trouble at all. All of our troubles have come from the sand beds fouling as described by Prof. Talbot in his paper. As he says, we have managed to keep the filter in fairly good working order by extra labor on the sand beds. The substance that collects through the sand bed is very tenacious and requires more agitation to clean it than is given by the ordinary washing process.

We expect, during the coming spring, for the purpose of experiment, to remove the present bed from one of the filters and put in a larger proportion of gravel with about one foot of sand much finer than that now used to see if we can catch and hold the iron oxide on the surface of the bed, believing if we can prevent it from penetrating the sand bed much of our trouble will be over.

The effect of removal of iron from the water has pleased our patrons greatly. We do not receive one complaint now, where fifty came in before the filter was put in operation. Those of you who have the active management of water plants under your charge, will perhaps realize what this means towards making life more enjoyable.

The growth of crenothrix in the distribution system memtioned by Prof. Talbot, was the cause of most of our complaints from con-

sumers before the filters were put in operation. This growth had become quite heavy and most of our mains were affected. When the iron, or most of it, was removed from the water, there was nothing to nourish the crenothrix so that it died in the mains and imparted an odor and taste to the water. About this time the biennial story got afloat that a nigger baby had been found in the water works reservoir. The taste and smell of the water convinced many of our patrons that the story was true. The taste soon passed away. Frequent flushing of the mains hastened its departure, and has made the supply unobjectionable.

The State Water Survey under the direction of Dr. Bartow, has been of great help to us in planning methods of operating the filters.

We have installed a laboratory with simple apparatus for testing the effluent water for iron content. This will, no doubt, aid us considerably in the operation of the plant.

F. W. Mohlman: (By letter) Mr. Langelier and I have carried on experiments at the filter plant from September, 1913 to January, 1914. During this time we made several hundred determinations of the iron content of the raw and filtered water. From December 1st to January 15th, lime was applied at the rate of one grain per gallon to the water flowing into filter No. 4. This allowed a reaction period of only fifteen to twenty minutes. The time for reaction could not be increased without applying lime to all of the water in the upper reservoir; which was impracticable.

Analyses of the effluent of No. 4 compared with that from a filter operated without lime, showed an advantage of from .1 to .3 parts per million Fe for the lime-fed filter. No advantage could be noted in the condition of the bed. A more detailed account of the experiment, and the other results of our work at the plant will be given later.

W. W. DeBerard: (By letter) When looking at the plant the other day I had in mind to ask you whether or not you have ever considered the possibility of using an additional grid placed immediately above the sandlayer, while the latter was at rest, but which would be submerged in sand when the wash water was applied to the under drain.

I might say, that I tried this method at the experimental filters at Oakland in 1908 and found that I was able to wash the filters from the additional upper grid in an extremely efficient manner.

The squirting or jet velocity issuing from the upper grid had a chance to act directly on the sand grains. As you know, this jet velocity from the underdrain system is entirely lost before it reaches any of the lower sand grains.

We tried several different ways of turning the holes in the upper grid system; when turning them up we lost a great deal of sand which was carried over into the wash water trough. Finally we were able

to get just as good results without loss of sand by turning the grid holes so that they were directed downward and away from the trough. As I remembered it off hand, we used a 1/8 in. hole spaced about four inches apart and a minimum amount of water of about 0.6 feet vertical rise in the lower grid drain system and 0.4 ft. in the additional grid. No air was used and the sand was always in perfectly clean condition; in fact, so clean that we were not able to get much of any bacterial results.

We did not care in this particular case because the original water contains comparatively few bacteria, less than a hundred in most cases.

THE FILTER PLANT AT FLINT, MICHIGAN.

BY R. S. BUZZELL.*

Until the official opening of the new mechanical filtration plant in January of this year, the city's drinking water was supplied by individual wells.

Fig. 1. Filtration Plant, Flint, Mich. Exterior.

The present filtration plant (Fig. 1) is about one and a half miles above the city on the Flint river. It is the ordinary type of mechanical filter, total capacity 12,000,000 gallons per twenty four hours, having two coagulating basins of about 1,000,000 gallons each and a clear well capacity of 2,000,0000 gallons.

*Superintendent.

Fig. 2. Filtration Plant, Flint, Mich. Interior.

There are eight units, (Fig. 2) equipped with separate air manifolds, so that air and wash water can, if it is desired, be applied together during the wash. Each unit is equiped with loss of head gages, rate controllers and hydraulically operated valves.

At the present time aluminum sulphate is used for coagulant (Fig. 3) and the feed controlled through orifice boxes.

A hypochlorite apparatus is installed and so arranged that the solution can be added before the addition of the coagulant, also at a point before the water enters the filter beds and it can be applied, if necessary on the down stream side of the clear well.

The plant has been in continuous operation since July 1913, excepting several short periods when operations ceased for necessary adjustments. The water has generally a low bacterial content for a river water. There are many springs in the river above the intake and practically nothing more than drainage from farm lands emptying into the river above the plant. The specifications require the plant to produce an effluent containing not to exceed seventy germs per cubic centimeter, except when the germ content of the raw water exceeds 3500, then the effluent should show a removal efficiency of 98%.

The maximum bacterial content of the river water since beginning operations in July 1913 was 2170 per cc.; the minimum 75, plated on

Fig. 3. Coagulant Tanks, Flint, Mich.

1% Agar and grown at 37½° C. The maximum count on gelatin at 20° C was 22,050, minimum 135.

The bacterial content of the filtered water runs from two to ten germs per cubic centimeter. From one to three grains of coagulant per gallon have been used since July, 1913, and during the past winter months from one to two grains have given a good reduction of color.

The alkalinity has varied from 126 to 260 parts. The maximum color of the river water was 160 parts, but during the past winter months the color has been from 30 to 45, with a color of the filtered water from 8 to 15.

Hypochlorite has been used since January. .2 to .4 parts available chlorine eliminates all B. Coli in one and ten cubic centimeters of water, while gas formers are present in 1 cc. and 1/10 cc. of the river water. The average amount of wash water used is 2.5% of the amount filtered.

Before the plant was officially opened in January, 1914, colony counts and tests for B. Coli were made upon water from many taps in the city. The final test showed the germ content to be similar to the tap water in the laboratory. An important and valuable final test was

made for pathogenic organisms. Samples were collected from the intake and twelve different taps in the city. One cc. from each was inoculated into tubes of sterile bouillon and grown at 37½° C for twenty-four hours. The bouillon solution from the city taps after twenty-four hours growth were clear, while the raw water tube showed a high turbidity due to germ growth.

One cc. from each tube was then inoculated into the abdominal cavity of guinea pigs and the symptoms noted. The pigs inoculated with the cultures from the taps were unaffected, while a pig inoculated with 1 cc. of the culture of raw water died in eight hours. Bacteriological examination of the heart's blood, liver, spleen and exudate showed positive B. Coli in those organs.

The usual methods of keeping records and hourly loss of head

Fig. 4. Laboratory, Filtration Plant, Flint, Mich.

readings are taken by the attendant on duty, giving a good check on operations.

In our well equipped laboratory (Fig. 4), besides the routine methods of water analysis connected with the water purification work, we are beginning to do considerable chemical and bacteriological work for the city.

THE RAPID FILTER PLANT AT EVANSTON, ILLINOIS.

BY LANGDON PEARSE.*

In the interesting paper on the filtration plant at St. Louis, Mr. Wall has presented details of the largest rapid filter yet undertaken, which will filter water derived from one of the muddiest streams in the world. My paper will describe briefly a comparatively small plant, of twelve million gallons daily capacity, handling water from Lake Michigan. This size, however, is more akin to the problems which the average water-works official in Illinois has to meet.

The installation of a plant was urged by the State Water Survey and the health officials of Evanston because of the poor condition of the water in Evanston, both from the hygienic and aesthetic standpoint. The intake is only 1 1-6 miles offshore, well within the range of drift for the sewage of Evanston and Wilmette, the greater portion of which is discharged on the lake front. In the winter of 1911-1912 a severe threatened epidemic of typhoid was averted only by the emergency use of chloride of lime.†

When the matter was agitated in 1912, Mr. W. W. Jackson and the writer made a report, in August of that year, recommending the construction of a plant of the rapid-filter type. By a popular vote, in the same fall, a bond issue was authorized. Plans and specifications were prepared by Mr. George W. Fuller, of New York City, and the writer, on which bids were received in April. Active construction work commenced in June, 1913, under our direction, with Mr. C. G. Gillespie as the resident engineer.

Doubtless some of you will ask why the plant was made of 12,000,000 gallons capacity for an estimated population of about 30,000. The reason for this is the abnormal daily average pumpage in the summer time, the daily average frequently running 12,000,000 gallons per day for a continued period of hot weather, with peak loads for four hours as high as 17,000,000 gallons per day in the afternoon. The average daily pumpage by the year has been about 6,000,000 gallons per day for the last ten years (Fig. 1), the effect of increase in population having been taken care of by inspection of services and leaks. This large use of water is due principally to lawn sprinkling, since the pumpage drops suddenly in summer time on cloudy, and particularly on rainy days

*Division Engineer, The Sanitary District of Chicago.

†See Proc. Ill. Water Supply Assn. 1912.

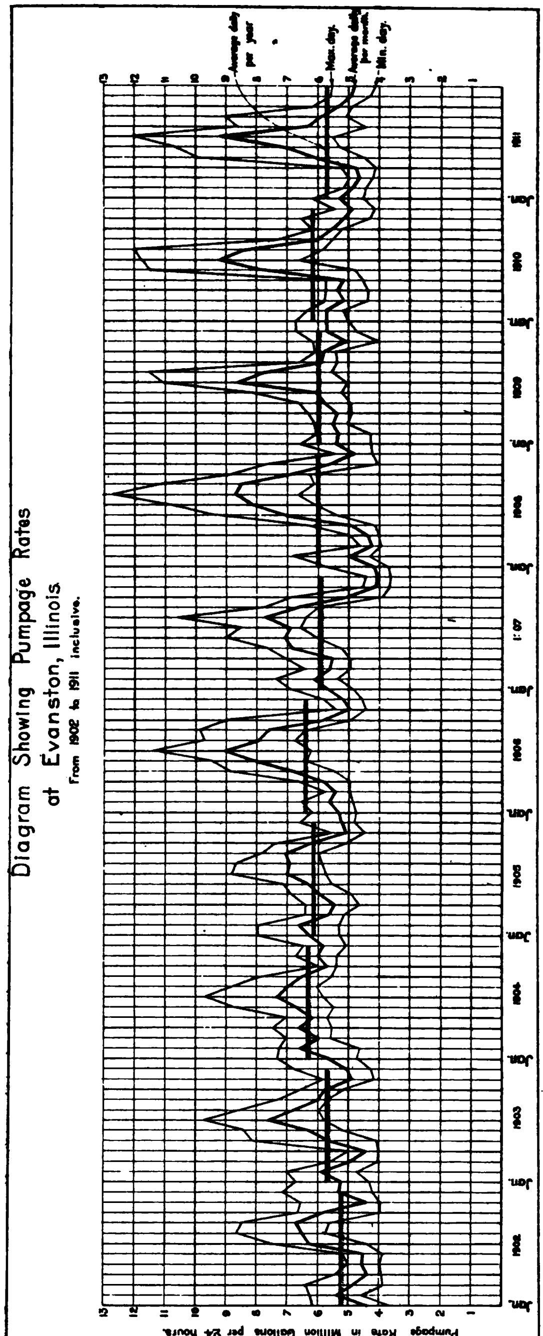


Fig. 1. Diagram showing Pumpage Rates at Evanston, Illinois.

(Fig. 2). With the condition in mind of continued daily loads, and the possibility of a healthy growth of population, 12,000,000 gallons capacity seemed a nominal size for this community. This rating is based on the usual rating of 125,000,000 gallons per acre per day.

The filter plant is located on Sheridan Road about one mile north of the center of the city on a site adjoining the Northwestern Univer-

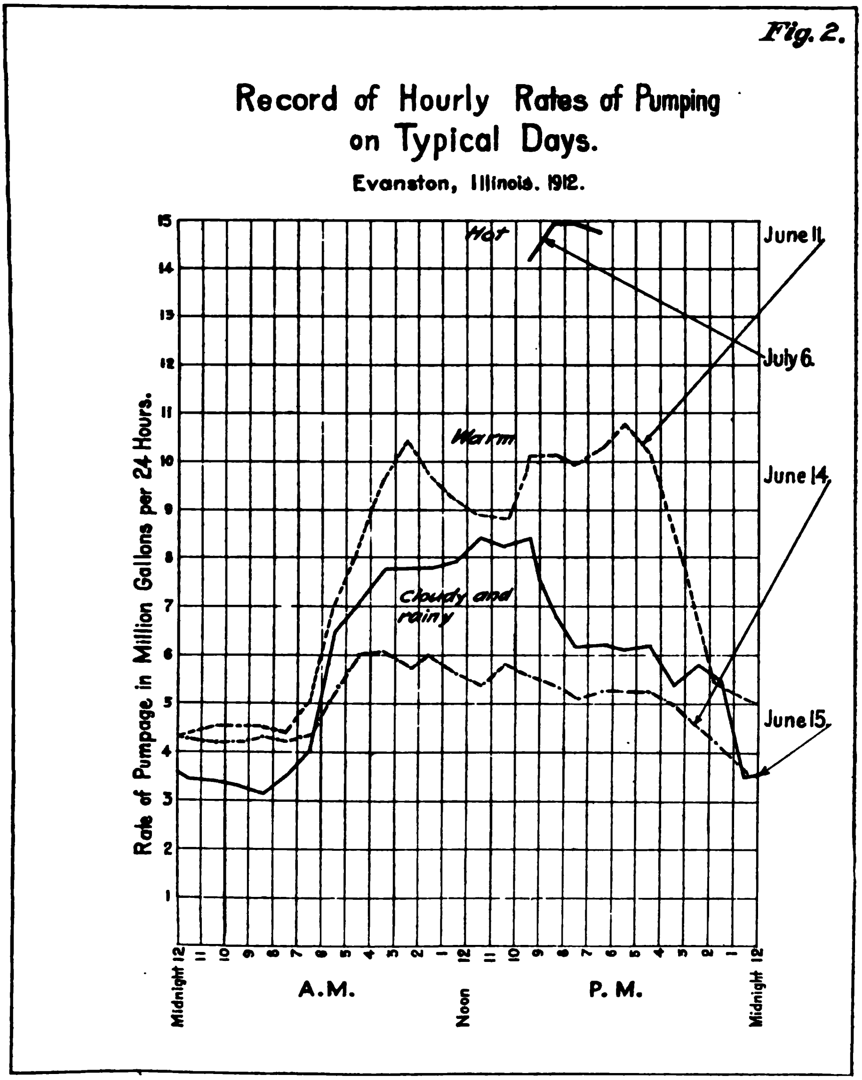


Fig. 2. Record of Hourly Rates of Pumpage on Typical Days, Evanston, Illinois, 1912.

sity and 300 ft. from the existing city pumping station. A low-lift pumping station is being built adjoining the present pumping station, which will be equipped with three centrifugal pumps, two of 10,000,000 and one of 6,000,000 gallons per day, capacity, with a lift of about 35 ft. These will be geared to steam turbines, the entire outfit being furnished by the DeLaval Steam Turbine Company, with a guaranteed duty in excess of 69,000,000 ft.-lb. per 1,000 lb. of dry steam for the larger units operating condensing with about 26 in. vacuum. A 30 in. cast iron force main will conduct the raw water to the entrance to the mixing chamber, a Venturi meter being placed on the line to measure the pumpage.

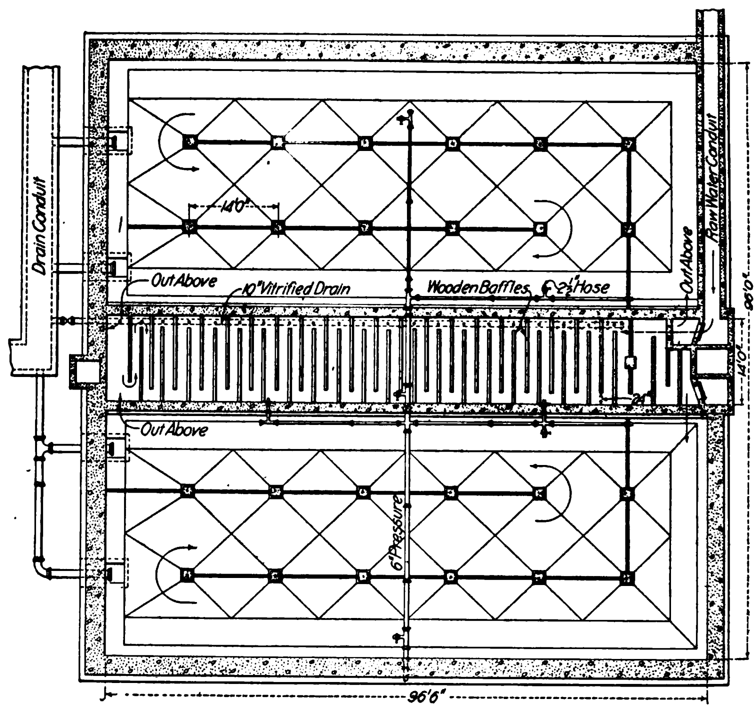


Fig. 3. Plan of Mixing Chamber and Coagulating Basins, Showing Baffles.

The mixing chamber (Fig. 3) is about 96½ ft. by 14 ft. in size, with a depth of 18ft., having a total capacity of approximately 170,000 gallons, giving a nominal mixing period of 20 minutes. The basin is to be constructed entirely of reinforced concrete, divided into bays by wooden baffles to maintain velocities of approximately 1 ft. per second. The mixing chamber lies between and is part of two coagulating basins (Fig. 4) each about 39½ by 96½ ft. in size, and 15 ft. deep, having a combined capacity of approximately 830,000 gallons, giving a nominal

period of sedimentation of 1 hr. and 40 minutes. These are to be constructed entirely of reinforced concrete with a groined arch roof, each compartment being divided by two concrete baffles into three bays to insure circulation.

The coagulated water will flow in a concrete channel across the space left for the extension of the filters to six rapid-filter units, each 23½ by 36 ft. inside diameter, having an aggregate filter surface of 4425 sq. ft. The filters will be grouped on both sides of a pipe gallery, over which is a platform with an operating table for each filter. All the filter tanks, floors and roof will be of reinforced concrete. Hydraulic valves will be used throughout, the controllers for the filters being of a modified Vivian type. The wash-water drain, filtered-water conduit and raw-water conduit will be built one over the other, forming a reinforced concrete structure down the center of the pipe gallery. The house covering the operating floor and a part of the filters will be of brick with a concrete roof, the inside being lined with a light yellow vitrified brick. The design is so made that the operator can see the entire filter bed at time of washing.

Both filters and head house are placed above a covered filtered water reservoir, 154 by 161 ft. in plan, 12 ft. deep, divided into two basins having a total capacity of approximately 2,000,000 gallons. This basin has a groined arch roof, reinforced where necessary to carry the weight of the head house and filters. The standard spacing for the arches is 12 ft. 6 in. on centers, with a rise of 2 ft. 9 in. and a thickness of 6 in. at the crown. The foundation is of firm clay so that the thickness of the floor arches is only 6 in. at the thinnest point.

The two-story head house at the head of the filter gallery has two wings, one story each, built of reinforced concrete and brick with prepared roofing. The dimensions of the head house are approximately 28 by 91 ft., and of the filter wing 75 by 36 ft. In the head house will be placed the tanks and apparatus for the proportioning and application of the coagulating and sterilizing chemicals, the recording gages, laboratory office, and chemical storage. The second floor of the head house will be served by an hydraulic elevator.

The design of the rapid-filter units includes an under-drain system with perforated brass plates, set at the bottom of valleys in the fashion of the Minneapolis, Grand Rapids, and other plants (Fig. 5). A novel feature, however, will be the omission of the wire screen and the use of 12 in. of graded gravel, on top of which the sand will be placed. The wash is to be high-rate water wash, supplied by a gravity feed from a steel tower tank of 100,000 gallons capacity erected behind the present pumping station on the lake front by the Chicago Bridge and Iron Works. It will be fed by a bleeder from the present high service mains. Fluctuations in the pressure due to the drop of level in the

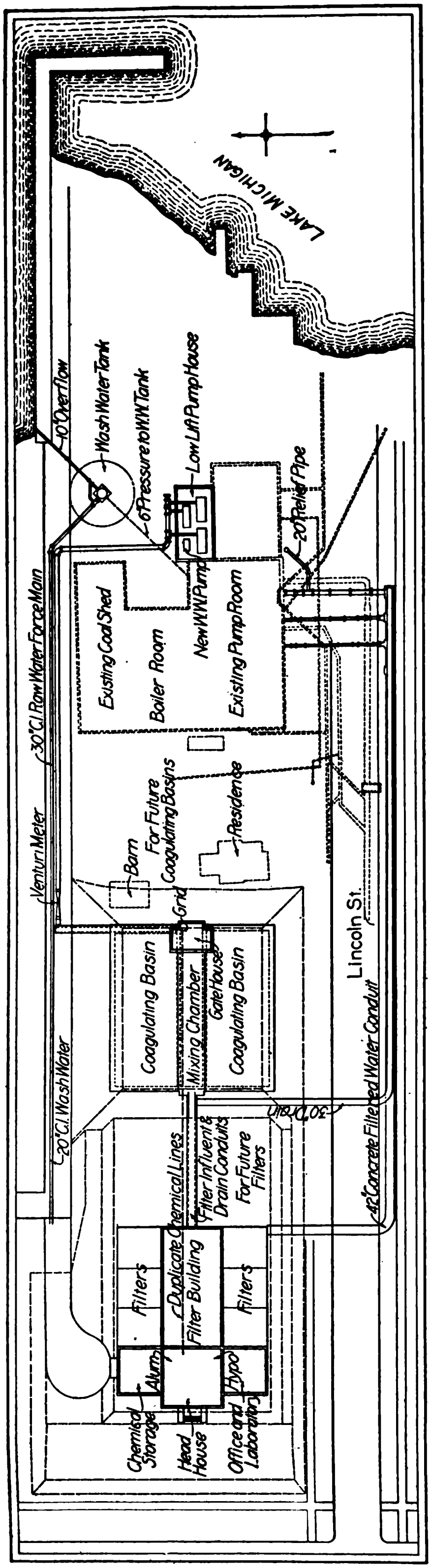


Fig. 4. Relation of Tanks, Filters and Mechanical Equipment of Evanston's Filter Plant.

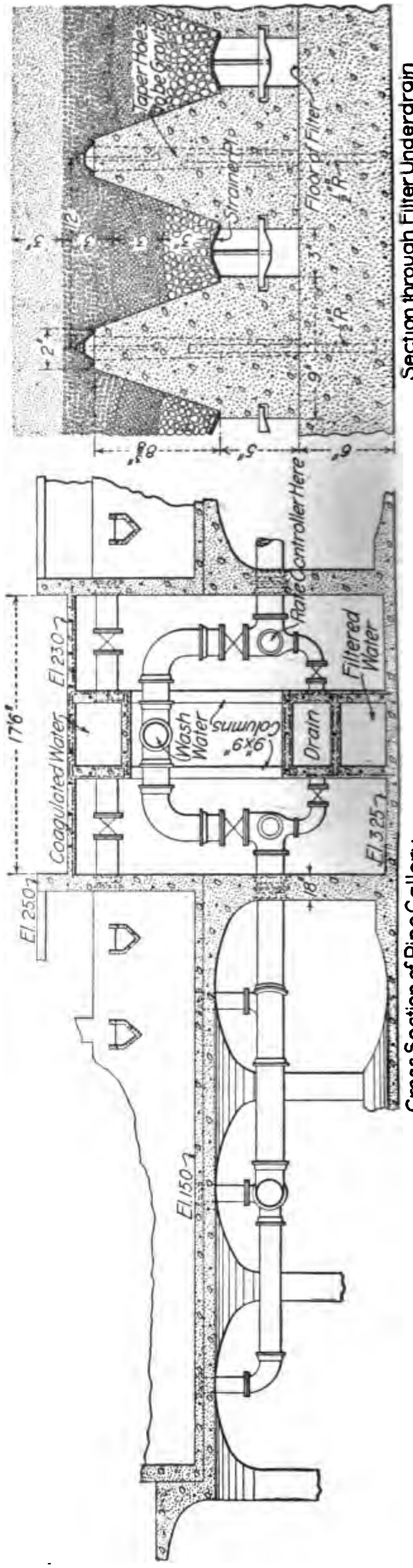


Fig. 5. Cross Section of Reservoir, Pipe Gallery and Underdrains, Evanston Filter Plant.

wash-water tank will be taken care of by a controller to be placed in the line at the entrance to the filter gallery. (Fig. 5).

The work is being carried on under a general contract with the Norwood Engineering Company, Florence, Mass., the concrete work, head house, and excavation being sub-let to the Macdonald Engineering Company, Mr. James Macdonald, President. Owing to the situation, it was impossible to bring material in except by teams, a haul of approximately one mile from the nearest railroad switch, being required.

Fig. 6. Steel Screed for Inverted Groined Arches.

The contractor, therefore, has developed a plant for the elevating and storage of the gravel and sand in bins to minimize the handling by hand. The teams dump into a hopper from which a belt conveyor delivers the material to the sand or gravel bins. Storage sheds for cement are built alongside the bins. A Ransome concrete mixer discharges into two-wheeled buggies on an elevator for raising or lowering the cars of concrete to the appropriate level for placing. One inch yellow pine flooring has been used for form work wherever possible, with 2 by 4 in. studs spaced about 16 in. on centers tied with very heavy wire.

The inverted groined-arch column bases were formed up continuously in rows by the use of a "spider," a metal frame consisting of 1-in. angles making a square, from each corner of which malleable castings of the shape of the groin converged to the base at the center, where they were held together by plates. In use, the angle frames was set on the two 6-in. floor form strips and held there by pins. After running a cut-off strip over each pair of legs and getting the base shaped, the form was removed to the adjoining base and the corners smoothed up.

The groined-arch forms (Fig. 7) for the roof have been built in a manner different from that usually employed on such work. The form units are framed in the carpenter shop and transported to place on

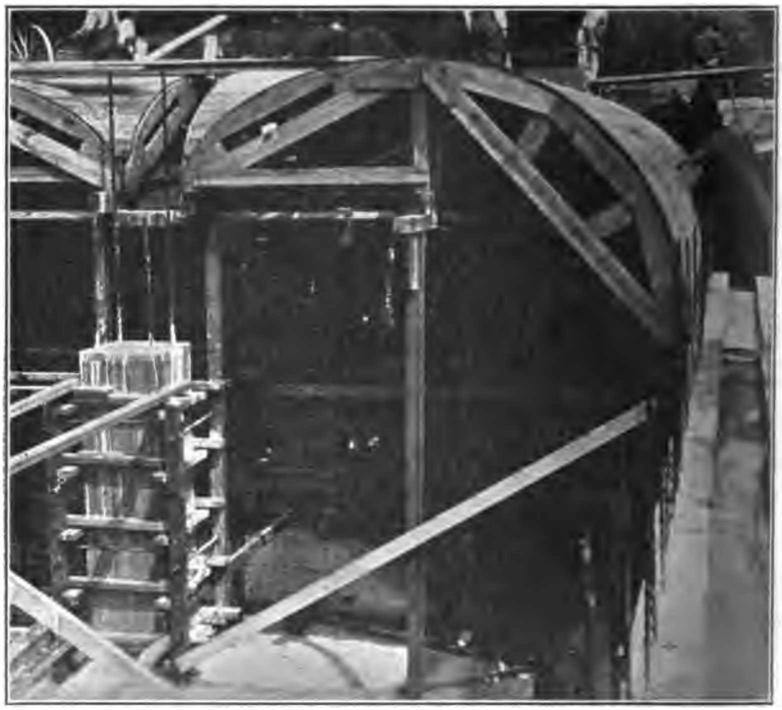


Fig. 7. Forms for Groined and Barrel Arches.

a pair of wheels. They fill the squares between the column corners, leaving a width approximately that of the column to be filled on the job, with short pieces of 1 in. flooring nailed in place by carpenters (Fig. 8). This method was feasible because of the short span. The groined-arch forms were carried on stringers resting on the vertical tie studs of the column forms. The forms have been stripped at a minimum time of five to seven days, ten days being secured wherever possible. For the construction of the 30 in. wash-water drain and 42 in. filtered-water conduit, suitable circular collapsible forms were built of wood. At the bends a built-up form has been used, made of laths, plastered smooth with ivory wood-fiber plaster, smoothed up with paraffine wax dissolved in kerosene. The forms were destroyed before removal.

In the construction of the chemical solution tanks in the head house and the valve chamber at the entrance to the mixing chamber,

the Macdonald Engineering Co. has used a novel adaptation of the moving form used in grain elevator construction. The form (Fig. 9) consists of well braced sheets making an inside and outside form 4 ft. high. This is supported by hangers carried on jacks which are moved up-

Fig. 8. Adjustment Space Between Arch Forms.

Fig. 9. Moving Form for Chemical Solution Tanks.

wards on stout iron rods embedded in the concrete. The twisted steel is placed as the form moves upward. The idea is to move the form upward at such a rate that the concrete exposed below the form will be set sufficiently to be self-supporting. As a result, a very smooth finish can be obtained at small cost. Clearly, such a method is appli-

cable only where a structure has the same plan throughout its height. In the case of the solution tanks the form was jacked upward day and night for five days through a height of about thirteen feet. A similar device is being used to build the reenforced concrete baffles in the coagulating basins, the reenforcing however being placed first and each side form being jacked up separately.

In the filter boxes the gutters are cast in place prior to the forming of the underdrains. Neat rounded edges are secured by a metal screed tool. The underdrain system is being cast in place, complete, instead of casting the spanning block outside and placing later. The procedure has been as follows. Holes were drilled in the floor to receive the dowels. For this work a small forty-pound Ingersoll-Rand steam drill was found most economical. In these holes, the dowels were grouted, a test being made after ten days set. Then the brass deflector plates were set over the three rising pipes in the bottom of the filter, and the bottom thoroughly cleaned. The forms were then built up as shown in Fig. 10. The bottom pieces to form the waterways were

Fig. 10. Ridge Block Form, Evanston Filters.

carefully adjusted and set in lime cement mortar. They are separated by removable wedges. On these sit the block forms. The entire wood forms have been made up for three one-quarter filter units, and are thoroughly treated with one part kerosene and two parts paraffine applied hot. Small blocks are left to form the indents for the yokes. The essential points are to preserve full waterways and obtain true level seats for the brass strainer plates.

The excavation has been made on all the mass work with a Thew shovel, loading two-horse bottom-dump wagons with which the spoil was carried to adjoining lots or dumped on the lake front. The earth was fairly stiff, so that no sheeting was required except in trenches left open for days. The upper 5 ft. of excavation was loam and sand containing some water, under which a clay stratum was found, free from water. Some of the sand from the excavation was suitable for use in the concrete, but the major portion of the concrete was made with torpedo sand and gravel brought from pits along the Fox River. The imported sand was found somewhat unsuitable, owing to the lack of fine material, so that a mixture was made of one part plastering sand and five parts torpedo sand for general use. This made a nicely-working tight concrete.

At present (March 9, 1914), the work has progressed through the completion of the filtered water basin. All six filters and the head house (Fig. 11) have been finished. The gutters and underdrains are

Fig. 11. Head House, Evanston Filters.

being poured. Filter piping is being rapidly installed. The coagulating and mixing basins are nearly complete. The wash-water tank has been erected, the low-lift pump house nearly completed, and most of the outside piping, conduits, and drains put in place. It is the intention to have the work completed as nearly as possible by the contract time next spring, May 31, 1914.

In conclusion I wish to acknowledge the courteous assistance and co-operation of the city officials, in particular the Water Committee, and Mr. J. H. Moore, Commissioner of Public Works, and the continued interest of Mr. M. O. Kasson, Superintendent for the Macdonald Engineering Co.

DEATH OF B. COLI AND B. TYPHOSUS IN PURE WATER.

BY OTTO RAHN, PH.D.* AND M. E. HINDS**

The rate and manner of death of bacteria in drinking water and in polluted streams, and the different factors which influence this death, are of considerable importance to water works men, and in the case of pathogenic bacteria, to the health of men and animals. A knowledge of the longevity of *B. coli* is of aid in determining the length of time a sample may be kept between sampling and analysis and it may also be of value in determining the volumes to be used in the analysis of the sample. A knowledge of the longevity of *B. typhosus* is necessary for the purpose of determining the presence of the organism itself, and also to determine the chance of infection from a stream which may be contaminated with that organism.

As a number of uncertain factors would be involved in working with a natural water or sewage, it was thought best to work first on pure water under known conditions and to vary the conditions until they finally approached those found in natural waters. The water used for this work was ammonia free, but contained a very small amount of nitrogen. It is purer than ordinary distilled water, having been redistilled, and is the purest grade of water obtainable unless an unusual amount of labor is spent on its preparation.

The rate of death of *B. typhosus* as found by different observers is variable, probably due to different experimental conditions. Of the many contradictory statements concerning the death rate, it is difficult to determine which one is correct as most of the data appear to be reliable. This leaves us in doubt as to whether death is due to lack of food, presence or absence of oxygen, temperature changes or antagonism of other bacteria.

During the last seven years we have learned that bacteria under unfavorable conditions die gradually. Of the total number, a certain percentage will die in a unit of time and of the number surviving the same percentage will die in the next unit of time. As far as we know, this law holds true with all causes of death, whether by disinfectants, light, drying or heat. We know of no exception.

*Assistant Professor of Bacteriology, University of Illinois.
**Assistant Chemist, Illinois State Water Survey.

It was only natural to expect this same regularity of death to hold true in case of *B. typhosus* and *B. coli* in pure water. The experiments showed this to be the case. The reduction in the case of *B. typhosus* was 89.3 per cent in six hours, i. e., after six hours time only about ten per cent of the original number survived. Assuming 1,000,000 cells to be present in the beginning, we find the following numbers remaining, based on a reduction of 90 per cent in each six hour period.

TABLE I.

Hours	Theoretical number of cells	Actual number of cells
0	1,000,000	315,000
6	100,000	40,000
12	10,000	937
18	1,000	—
24	100	Less than 1
30	10	
36	1	
42	.1	
48	.01	
54	.001	
60	.0001	

Another experiment shown on the curve (Fig. 1) shows actual results similar to the theoretical.

It is easily seen that we never come to an absolute zero. There are always some bacteria left alive, but the number soon becomes so small, that for practical purposes, we might consider them absent. Table I shows a reduction in sixty hours from 1,000,000 per c. c. to less than 1 per gallon. Whether such water would be considered safe for use, is questionable. In ninety-six hours, we would have less than one typhoid bacterium per 1,000,000 gallons. Such water would probably be safe. Certainly, no bacteriological or other analysis could discover the bacterium.

B. coli does not die quite as fast as *B. typhosus,* about seventy-two hours being necessary to reduce their number from 1,000,000 per c. c. to one per gallon. Kruse states that *B. coli* is found a normal inhabitant of all waters, whether good or bad. We can find it, if we only take a large enough sample.

Knowing the facts, we tried to find the cause of death. It is probable that the death of *B. coli* and *B. typhosus* in pure water is due to starvation. A sample of tap water was sterilized and inoculated with *B. coli* and proved to be a fair medium for growth. An initial number of 1,500,000 increased slowly to 3,000,000 in twelve days and then slowly decreased, over half the original number being still present at the

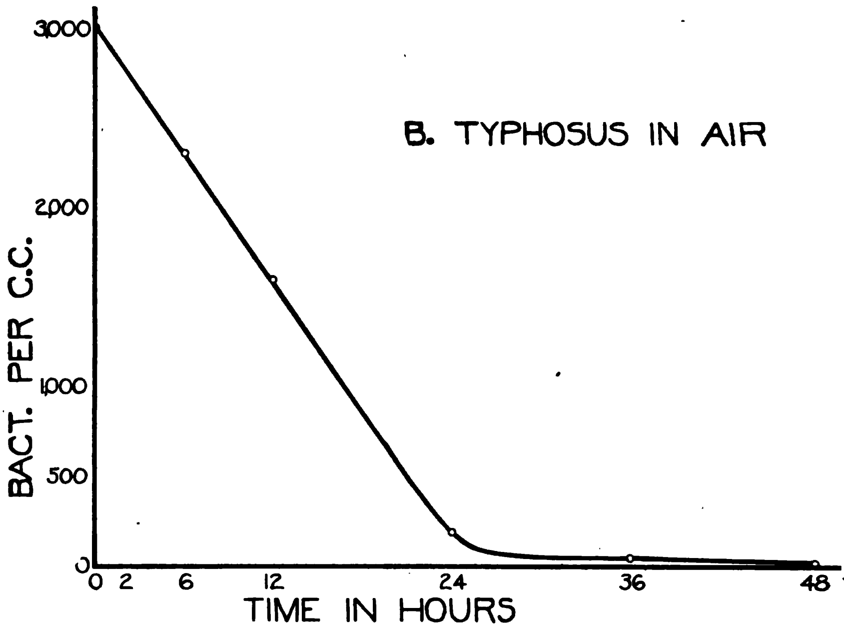


Fig. 1. Death of B. Typhosus in Air.

end of five weeks, when the experiment was discontinued. At the same time a sample of deep well water with a very high mineral residue was sterilized and inoculated with about 2,000,000 *B. coli* per c. c. and only one per c. c. was found at the end of two days. This death rate was higher than in very pure water. Only a trace of organic nitrogen was present.

It is very important from a practical view point to decide whether or not dissolved oxygen plays any part in the rate of the death of bacteria in water. Whipple and Mayer found that *B. typhosus* died about twenty times as fast without oxygen as with it; and *B. coli* died about twice as fast. The absence of oxygen was secured by keeping the tubes in an atmosphere of nitrogen and hydrogen. This would suggest a suffocation of bacteria. In our work we have been unable to get the same results with *B. coli*, as in all of our tests the death rate was lower without oxygen. Our work on *B. typhosus* bears out the previous work in that the death rate is higher in nitrogen than in air, but the difference is slight as compared with Whipple's, perhaps due to a different strain, perhaps to different water. Figure 2 shows the difference in death rate in air, hydrogen and nitrogen.

The temperature of the water has a direct bearing on the death rate. Even though *B. coli* and *B. typhosus* both grow much better at 37° than at 20° when cultivated under growing conditions, they also

die faster at the higher temperature, with *B. coli* we have found the rate of death to increase 1.8 times with each 10° rise in temperature. Growth and death of bacteria must be looked upon as chemical reactions, and, therefore, must proceed faster at higher temperature within certain limits. In work with *B. typhosus* in Lake Michigan water, Russell found the death rate increased eight times from freezing to 12°C.

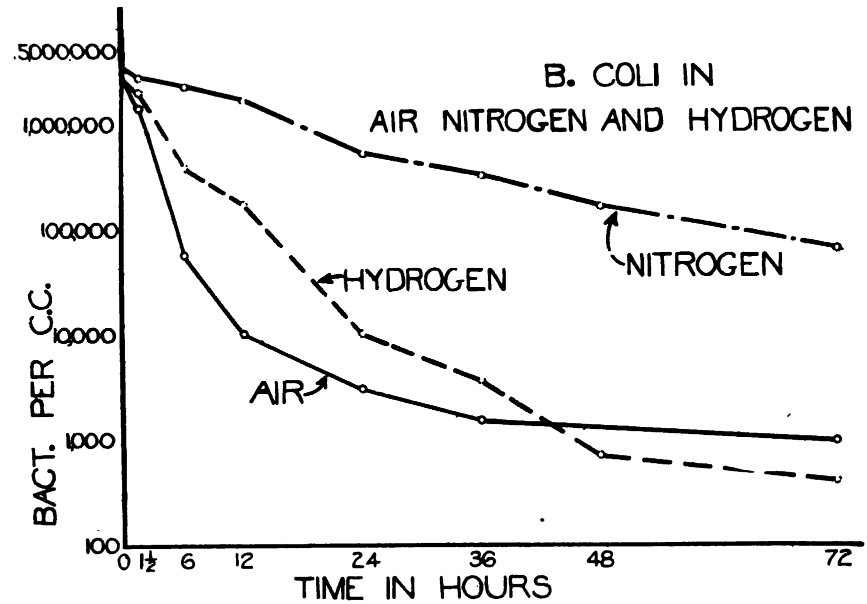


Fig. 2. Death of B. Coli in Air, Nitrogen, and Hydrogen.

In 1911 Ruediger determined the rate of death of *B. coli* and *B. typhosus* in river water under natural conditions both in summer and in winter. He attributes the faster death rate in summer to the effect of light and to saprophitic plants. We can account for the change in death rate as a change due to the difference in temperature.

CONCLUSIONS.

In pure, natural water and in redistilled water, *B. coli* and *B. typhosus* die from starvation in the gradual, regular manner observed with other causes of death.

The rate of death increases with the temperature.

The presence of oxygen under these conditions, seems to be harmful to *B. coli,* but beneficial to *B. typhosus.*

Further work is to be done on the effect of organic matter, mineral matter, other organisms and the temperature coefficient under varying conditions.

SURFACE WATER SUPPLIES OF ILLINOIS.

BY PAUL HANSEN AND RALPH HILSCHER.*

The following paper contains a few of the more general data to be embodied in a report which will be published in the annual bulletin of the State Water Survey for 1913.

There are in all about 280 public water supplies in the state of Illinois exclusive of Chicago. Chicago will not be considered in this report on account of its very large size and the preponderating influence which it would exert on the figures to be presented. The above number represents about 77 per cent. of the cities and villages having a population of over 1,000 and includes an aggregate population of 1,580,000. Seventy-three of the supplies serving 43.2 per cent. of the above population are of surface origin. Of this population, 72 per cent. is served with purified water supplied by 36 different plants.†

Generally speaking, smaller communities of the state seek ground water supplies, but in many instances, such supplies are not available in adequate quantity or of satisfactory quality. It then becomes necessary to secure water supplies from surface sources. A few municipalities have adopted surface supplies because of their easy development or because ground water resources of satisfactory quality and quantity were not discovered. Some of these communities notably, Springfield, Jacksonville, and Elgin, are reverting to the use of ground water supplies.

The state may be roughly divided into two parts by an east and west line through Champaign, north of which ground water supplies are the more numerous, and south of which surface water supplies are in the majority. North of the line 14 per cent. of the supplies are of surface origin, and if the smaller surface supplies drawn from Lake Michigan are eliminated, this figure is reduced to 7 per cent. South of the line 57 per cent. of the water supplies are of surface origin.

The explanation of this lies in the fact that throughout the northern half of the state, well waters are generally available in sufficient quantity and of satisfactory quality to meet the requirements of a public supply. In the northern quarter of the state, most of the sup-

*Engineer and Asst. Engineer, Illinois State Water Survey.

†Water purification in Illinois, Proc. Western Society of Engineers, 18, 934.

plies are derived from the St. Peter and Potsdam sandstone, found at great depths. In the quarter of the state lying just north of the line through Champaign, deep wells in the glacial drift constitute the principal water source for public supplies. Within this area, large quantities of water may also be drawn from the underlying rock strata, but this water is so highly mineralized as to be quite unsatisfactory.

In the quarter of the state just south of this line a number of supplies are obtained from shallower drift deposits of glacial or alluvial origin. All rock wells throughout this region are highly mineralized and are very little used. Some of the drift waters contain sufficient mineral matter to make them unsatisfactory. In the southernmost quarter of the state, ground water in adequate quantity and of satisfactory quality is seldom available, so that in this section, the great majority of the supplies are of surface origin. A few notable exceptions to the general rule are found in some deep wells in the limestone rock on the slopes of the Ozark uplift, exemplified by the public supply wells at Anna and Mounds. There are also wells in the deep alluvial drift of the Ohio river, which give large yields of a satisfactory water, exemplified by those of Metropolis.

Of the 73 surface water supplies, 36, or 49.3 per cent., are from streams, practically without storage. Nineteen, or 26 per cent. are from impounding reservoirs. Thirteen, or 17.8 per cent. are from Lake Michigan and five, or 6.9 per cent. are from streams with or without storage and supplemented by wells. Fifty-eight per cent. of the water supplies drawn directly from streams are treated by filtration or otherwise; 16 per cent. of the reservoir waters are treated; all of the supplies from Lake Michigan are treated and 3 of the five mixed water supplies are treated.

Some indication of the favor which surface water supplies meet on the part of the public, is indicated by figures showing the number of persons per service. With a generally used public water supply, the number of persons per water service is from 5 to 6. It is found that in Illinois, the number of persons per service in towns having surface water supplies, is as follows:

For waters drawn from streams, 7.

For waters taken directly from impounding reservoirs, 15.

For waters taken from Lake Michigan, 5.2.

For waters of mixed origin, 8.1.

Some general studies were made with reference to rainfall and run-off. Rainfall records are available for a long series of years at various points, but run-off records are very meager. In a general way, it is found that the maximum annual rainfall for the entire state is 43.45 inches and the minimum 32.07 inches.

The variations in run-off are exemplified by the Rock river at

Rockford in the north and the Kaskaskia river in the south. The northern river has a rolling watershed with large areas of porous soil and a number of tributary lakes which act as natural storage reservoirs. The average run-off for this stream based upon available figures is 27.7 per cent. of the rainfall. The Kaskaskia river on the other hand has a generally flat watershed, and a clayey soil which is relatively impervious. The run-off from this watershed is 37.7 per cent. of the rainfall. These figures are not, however, of general applicability as instanced by the run-off from Big Muddy river. This watershed is similar in many respects to the Kaskaskia, but the run-off is only 22.9 per cent. of the rainfall.. Beaucoup Creek has, according to available figures, the very small run-off of 15.8 per cent. These low percentages of run-off, may be explained in part by some local peculiarities and in part by the unreliability of the limited data available.

A weighted average of run-off which takes cognizance of the variation of area and rainfall on the several watersheds for which such figures are available gives a figure of about 30 per cent. In the light of present knowledge, it appears inadvisable in estimating the yield of a watershed for water supply purposes to count upon a run-off greater than 20 per cent. of the minimum rainfall or, roughly speaking, about 100,000,000 gallons annually per square mile of tributary watershed. More accurate data on run-off for limited watersheds is greatly needed in Illinois, because under present conditions it is difficult to secure a sound basis for the selection of surface water supplies where impounding reservoirs are necessary.

Referring to the quality of the surface water supplies of the state, it may be said in a general way, that they are all subject to high turbidities, are more or less colored, and rather highly mineralized, but less highly mineralized than ground waters. Lake Michigan under normal conditions furnishes a highly satisfactory water supply, being but moderately hard and free from turbidity and color. In-shore winds, however, rapidly render the water turbid for distances as great as five miles from shore. Generally speaking it is impracticable to secure a useable supply with reference to turbidity within one-half mile of shore. The sanitary quality of Lake Michigan water is also subject to criticism at the present time inasmuch as it receives the sewage pollution of various north shore communities. This pollution at certain points extends many miles from shore and the water except as drawn from some of the long Chicago intakes, is not suitable for domestic consumption without purification.

The character of the waters of the streams in the state varies widely. During periods of flood, all of them are excessively turbid. This turbidity varies from a dark brown to light yellow in color, depending upon the surface soil. Many of the streams become quite clear during

periods of low water, but others retain their turbidity even then. Those streams that become clear during low water are generally fed in large measure by springs that enter along the stream beds. Those that retain their turbidity do not receive diluting ground water and the turbidity results from exceedingly finely divided clayey matter in colloidal suspension. Waters which are stored in impounding reservoirs lose a large proportion of their turbidity and color, but in very few instances does the water become sufficiently clear to constitute an entirely acceptable supply.

The mineral content of stream waters varies greatly, with a maximum of about 600 parts per million of total hardness and a minimum of about 45 parts.

Stored waters offer some problems in connection with tastes and odors due to development of plant life and microscopic organisms. Difficulty of this character arose at Waterloo and was successfully overcome by treatment of the water with copper sulphate.

Although drawing water from a surface stream or lake would seem to be a simple matter, nevertheless much intake trouble has been encountered in connection with surface water supplies of Illinois. The most pronounced of these troubles have been encountered along the Mississippi river where shifting sand bars sometimes completely cover and render useless an intake, as was the experience at Granite City. At Alton, an intake pipe which was laid six feet above the bottom was on the point of being covered by a sand bar resulting from navigation improvements carried out by the United States government at a short distance above. The difficulty was met by building an embankment wing dam over the intake and arranged so as to cause a scouring current to pass across the end of the intake pipe.

Along Lake Michigan, intakes involve costly construction for the purpose of getting beyond the influence of high turbidities and excessive pollution. Also difficulties are encountered due to the obstruction of intakes with ice. In a general way, it is found cheaper to overcome the difficulties due to pollution and turbidity by the construction of filtration works rather than by the costly extension of intake pipes miles into the lake. The elimination of ice troubles is a problem that has not yet been fully and satisfactorily solved. The prime cause of the clogging of intakes by ice seems to be the entrainment of newly formed spicules and plates of ice by vortical currents induced by the suction on the intake pipe. These vortices can only be eliminated apparently by securing an exceedingly slow motion of the water in passing into the intake pipe. This has been successfully accomplished at the Naval Training Station where a large wooden crib, with a great area of slotted openings, is used. Similar results have been secured at Rogers Park

where the intake pipe terminates in a large steel cylinder perforated with numerous small holes. This device is described in the report of this Society for 1912, page 110.

By way of summary it may be noted that many communities in Illinois, more particularly in the southern part of the state, are dependent for their water supplies on surface streams. These supplies are generally less favored than are ground waters of usable quality for domestic purposes. In all instances surface waters may be rendered entirely satisfactory from a sanitary point of view, by well established methods of water purification. Purified surface supplies because of their relatively low mineral content are often superior to ground waters. The data relative to run-off is inadequate to enable engineers to design surface water supplies with necessary precision and economy and further data of this character should be secured. There are throughout the state many instructive experiences with intake troubles, more particularly as these relate to shifting stream bottoms and ice.

EFFICIENCY OF THE TRIPLE EXPANSION PUMPING ENGINE.

BY WALTER REID.*

The City of Springfield, Illinois, in the year 1911 commenced the reconstruction of its pumping station at a cost of approximately $55,000, and also contracted for a pumping engine at a cost of $52,369. These improvements have been made under the direction of W. J. Spaulding, Commissioner of Public Property.

The pumping engine is of the Holly, vertical, triple expansion, crank and flywheel type with a normal capacity of 10 million U. S. gallons per 24 hours. The engine was erected by the Holly Manufacturing Co. at the city's pumping station on the banks of the Sangamon River, four miles north of the city.

The dimensions of the cylinders are: high pressure, 26″; intermediate, 48″; low pressure, 72″; stroke, 42″. All of the steam valves are of the Corliss type, as are also the exhaust valves of the high pressure and intermediate; but the low pressure are of the poppet type.

The diameter of the steam pipe is 6″; exhaust pipe, 20″; suction, 30″; discharge pipe, 24″. There are three water plungers 23″ in diameter of 42″ stroke. The plungers are outside packed, and are directly under the steam cylinders. The pump end contains 1050 rubber valves 3⅜″ in diameter, and are so located that they are very accessible. A condenser of the surface type is located in the suction pipe, and it has 1,000 square feet of cooling surface.

The duty guaranteed by the builder per 1,000 pounds of dry steam consumed by engines, its jackets and attached auxiliaries at normal capacity and pressure (277 feet) was 170,000,000 foot pounds. Duty three-quarter capacity, 165,000,000 foot pounds. Duty one-half capacity 160,000,000 foot pounds. The normal capacity rated at 7,000 gallons per minute based on plunger displacement and a total head of 277 feet, maximum 375 feet. Steam pressure at throttle 150 pounds, 32 R. P. M. which is equal to a piston speed of 224 feet per minute.

On January 21st, 1914, the necessary gauges were connected to the discharge and suction pipes, tanks for collecting, and scales for weighing the water from the jackets, receivers, and discharges from

*Superintendent Water Department, Springfield, Illinois.

condenser were all placed and tested and corrected previous to the final test. A number of preliminary tests were run and adjustments of steam valves for the most efficient distribution of steam and equalization of load for each cylinder was made. The results of the actual tests are as follows:

TEST AT FULL SPEED.

Duration of test, 12 hours.
Steam pressure at throttle, 150.5 lbs. per square inch.
Vacuum in exhaust pipe, 27½".
Average revolutions per hour, 1959 (or 32.5 R. P. M.)
Average discharge pressure, 118.5 lbs. per square inch (273.35 ft.)
Average suction lift, 12 ft.
Difference in elevation of gauges, 2.5 ft.
Total water pressure, 287.85 feet.
Average total steam consumption per hour, 6344 lbs.
Condensation from jackets and receivers, 13.15%.
Moisture in steam, 2.28% (145 lbs.)
Total dry steam per hour, 6199 lbs.
Duty per 1,000 lbs. dry steam, 171,830,000 foot pounds (I. H. P. 459.6).

TEST AT THREE-QUARTER SPEED.

Duration of test, 4 hours.
Steam pressure, 149.8 lbs. per square inch.
Vacuum in exhaust pipe, 27¼".
Average revolutions per hour, 1461 (or 24.1 R. P. M.)
Average discharge pressure, 117.2 lbs. per square inch (271 ft.)
Suction lift, 11 feet.
Difference in elevation of gauges, 2.5 feet.
Total water pressure, 284.5 feet.
Average steam consumption per hour 4776 lbs.
Moisture in steam, 2.8% (134 lbs.)
Condensation from jackets and receiver, 12.75%.
Average dry steam per hour, 4642 lbs.
Duty per 1,000 lbs. dry steam, 169,256,000 foot lbs. (I. H. P. 346.3).

TEST AT ONE-HALF SPEED.

Duration of test, 4 hours.
Steam pressure, 150.3 lbs. per square inch.
Vacuum in exhaust pipe, 27¼".
Average revolutions per hour, 1068 (or 16.4 R. P. M.)
Average discharge pressure, 116.4 lbs. per square inch (269 feet).
Average suction lift, 10.5.
Difference in elevation of gauges, 2.5.
Average total water pressure 282 feet.
Average steam consumption per hour, 3580 lbs.
Moisture in steam, 2.34% (83.7 lbs.)
Condensation from jackets and receivers, 12.5%.
Average steam corrected for moisture, 3496.3 lbs.
Duty for 1,000 lbs. dry steam, 162,810,000 ft. lbs. (I. H. P. 282.2).

In order to insure accurate results readings were taken of the water pressure every ten minutes from a test gauge on the force main. Readings were then reduced to hourly averages in order to check the performance of each consecutive hour while the test was being made. Indicator diagrams were taken every hour from each of the steam cylinders in order to show the steam distribution, the speed being kept constant by a fly ball governor attached to the engine.

We have in our plant in addition to the Holly triple pump an old Worthington triple pump, 18″×29″×46″×24″—26½″×24″, of 8 million capacity and a compound pump, 24″×43″×36″—20″×36″, of 4 million capacity. At the conclusion of the pumping test we ran a comparative fuel test. The new Holly triple pumping engine consumed 3900 lbs. of coal to pump 780,000 gallons of water, which is equivalent to 1 lb. of coal per 200 gallons of water pumped. The Worthington triple, 6105 lbs. of coal per 800,000 gallons of water, which is equivalent to 1 lb. of coal to 131 gallons of water. The compound pump, 7800 lbs. of coal per 680,000 gallons of water, which is equivalent to 1 lb. of coal to 87.7 gallons of water. Screenings was the fuel used for these tests.

The difference between 200—131—87.7 gallons water pumped per 1 lb. coal indicates the economy to be realized.

DETECTION OF LEAKS IN DEEP WELLS BY ELECTRIC LIGHT.

LLOYD Z. JONES.*

The City of Galva is situated on the divide between the Illinois and the Mississippi Rivers. The City draws its water supply from the St. Peter sandstone which is found at a depth of 1381 feet, and the wells are drilled to depths of from 1477 to 1525 feet. The log of the wells is as follows:

	Depth
Soil and clay	62 ft.
Coal measures	455 "
Niagara limestone	882 "
Utica shale	1030 "
Hudson River shale	1055 "
Trenton limestone	1381 "
St. Peter sandstone	1475-1525 "

A study of the logs of wells at Rockford shows that the St. Peter stratum falls fifteen feet per mile from Rockford to Galva.

When the well was first drilled, twenty years ago, the water rose to within 150 feet of the surface, but for some time it has stood at 240-246 feet below the surface. The pump cylinders are 300 feet below the surface, and are always covered with water. The well is cased 110 feet with 12 inch tubing, and below this level it is cased with 9 inch tubing to bottom. The joint between the casings is of lead.

In 1906, the quality of the water in the wells seemed to have changed, and it was thought that a leak had developed in the casing. Accordingly, the pump was taken out, and a cluster of three electric light bulbs was lowered into the well. The lamps were connected by a long wire to the lighting circuit, and were provided with a shade above. The lowering of this light into the well was followed by the aid of a field glass. It was found that water was entering through a leak in the casing at the lead packed reducing joint, 110 feet below the surface of the ground. This was repaired.

In 1911, there were indications of another leak in the casing. The above process was repeated, and it was found that a leak had developed again in the lead joint.

The cause of the failure in the casing at this point is explained by the continual vibration of the earth, which is brought about by the running of heavy trains on the main line of the C. B. & Q. R. R. only one hundred feet away, and by the jar of our own pumps. The upper strata are of soft water soaked material. The pump and heavy masonry base are fastened to the top of the casing and the result is a rather top heavy structure somewhat analogous to a top heavy flag pole. The vibrations consequently tend to break the casing at its weakest point.

*City Engineer, Galva, Illinois.

RELATION OF SEWER OUTFALL TO WATER WORKS INTAKE AT QUINCY.

BY W. R. GELSTON AND EDWARD BARTOW.*

The typhoid fever epidemic of December, 1912, to February, 1913, was shown to have been caused by a polluted water supply†. To determine the source of the pollution, analyses have been made of several series of samples of water collected from the sewer and the river. The samples have been collected at different stages of the river in order to determine as accurately as possible the liability to pollution under varying conditions.

The sewer which would be liable to pollute the water is located at the foot of Broadway, as indicated on the map. Samples were taken (1) of the sewage before it enters the stream, (2) from the river near the outfall, (3) channel opposite pumping station, (4) river over intake crib, (5) river opposite Diamond Jo boathouse, (6) intake well at pumping station.

A comparison of series (1) and (2) shows that the sewage has a noticeable effect upon the samples taken from the river near the outfall. The effect on June 23 was not so noticeable as in the other cases, but even on that date the water near the sewer outfall was much worse than that of the river itself. The water taken at the channel opposite the pumping station (3) would hardly be affected by sewage from the Broadway sewer. Comparing this sample with samples taken from the intake well (6), we find a noticeably larger number of bacteria in the intake well. The number of bacteria along the shore opposite Diamond Jo boat house (5) is usually not as great as is found in the intake well. The samples taken from the surface at the intake (4), though slightly better, do not differ materially from samples taken in the intake well which would be drawn from below the surface of the water.

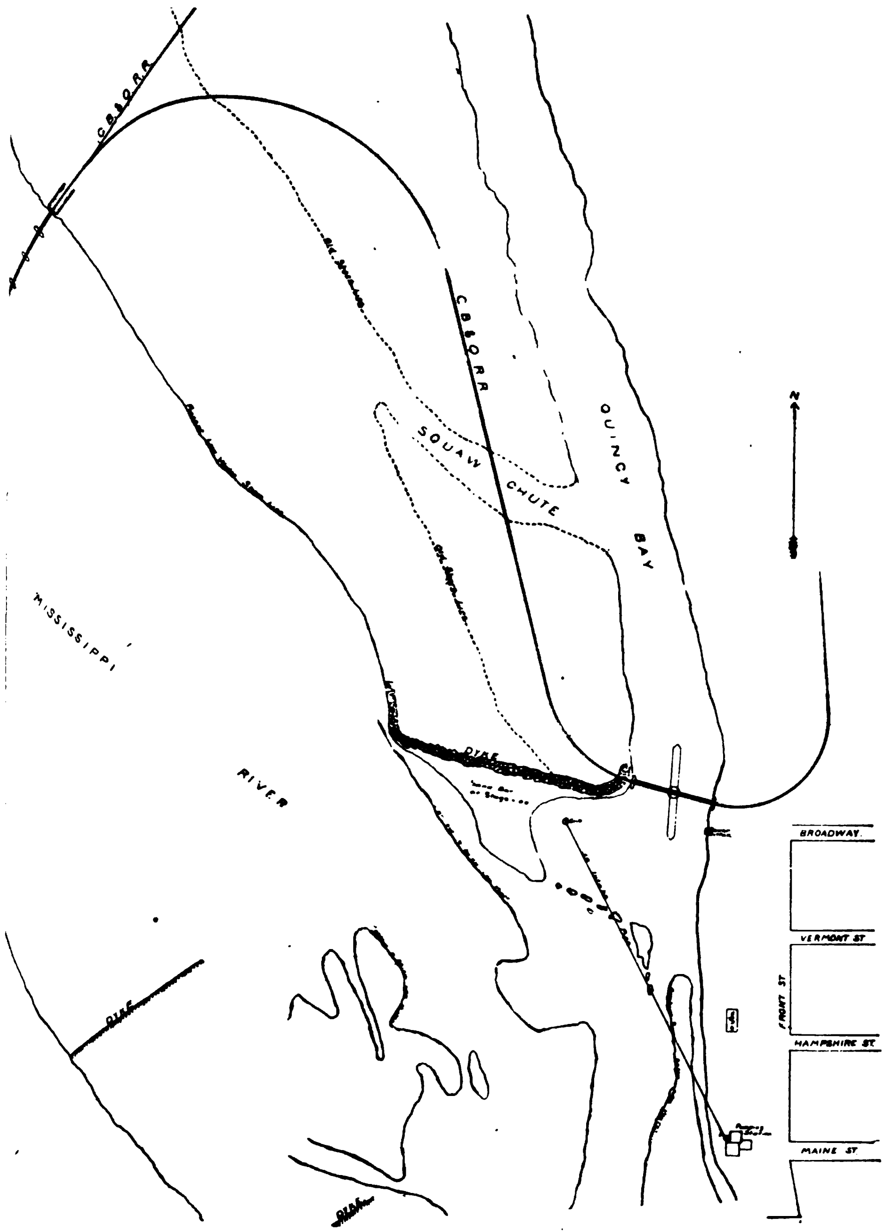
From the analyses, especially of the sample taken January 6, 1914, we must conclude that the Broadway sewer has a noticeable effect upon the character of the water at the intake. That this effect was more noticeable on the latter date is due in all probability to low

*Superintendent Citizens Water Works Co., Quincy, Ill., and Director Illinois State Water Survey, Urbana, Ill.

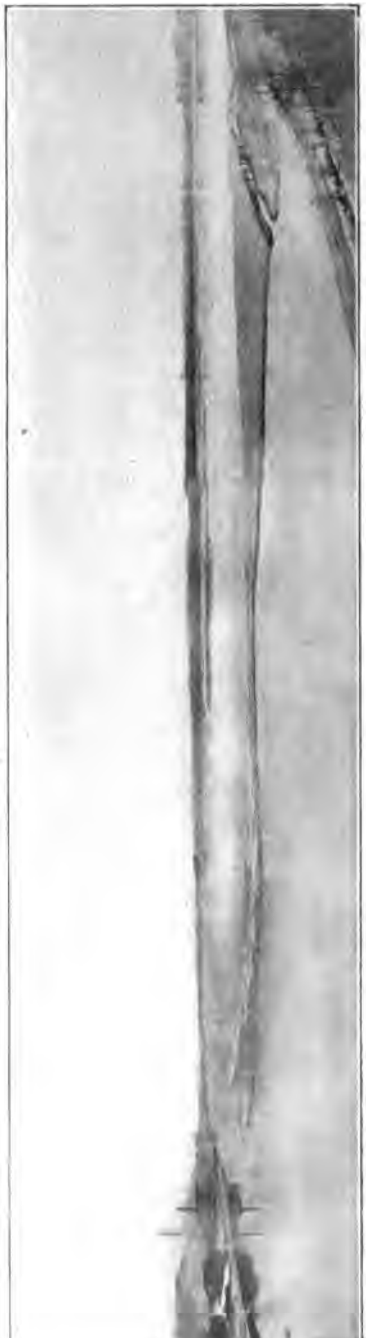
†Edwin O. Jordan, Proc. Illinois Water Supply Assn. 1913, 48.

TABLE SHOWING CHARACTER OF WATER AT SEWER OUTFALL IN THE MISSISSIPPI RIVER AT QUINCY.

Date of Collection	Lab. No.	Turbidity	Color	Odor	Residue		Chlorine	Oxygen Consumed		Nitrogen as						Alkalinity	Total Organic Nitrogen		Bacteria per cc.		Colon Bacillus			Indol
					Total	Dissolved				Free Ammonia		Alb. Ammonia		Nitrites	Nitrates									
								Tot.	Diss.	Tot.	Diss.	Tot.	Diss.				Tot.	Diss.	Gelatine	Agar	10cc	1 cc	.1 cc	
BROADWAY SEWER (1)																								
May 9—13	25234	300	40	5 S	871	390	83	80.0	7.8	40.0	24.0	7.20	2.00	.000	.56	350	....	....	1,000,000	400,000	1+	2+	2+	+
June 23—13	25507	225	140	5 D	1368	760	350	61.6	34.6	33.6	17.6	9.60	2.88	.000	.52	320	12.0	4.80	liq.	150,000	1+	1+1—	2+	+
Aug. 18—13	25916	950	100	....	2022	637	200	61.8	35.4	32.0	24.0	3.00	2.56	.000	.56	332	24.0	7.20	1,210,000	4,400.000	1+	2+	2+	+
Sep. 29—13	26202	280	140	5 S	744	476	74	59.0	31.0	21.1	16.0	9.28	1.76	.000	.64	324	....	....	3,300,000	36,000	1+	2+	2+	+
Jan. 6—14	26809	400	80	4 S	1300	667	81	56.2	39.7	43.2	33.6	8.64	3.52	.002	.60	350	20.0	5.20	4,000,000	3,000,000	1+	2+	2+	—
RIVER NEAR OUTFALL (2)																								
May 9—13	25235	160	40	3 S	344	152	23.6	27.6	14.6	3.20	5.92	2.40	.48	.000	.16	176	....	....	2,000,000	240,000	1+	2+	2+	+
June 23—13	25510	90	50	0	305	209	5.8	9.2	8.3	.32	.256	.384	.272	.044	.60	128	....	....	20,000	6,000	1+	1—1+	2+	+
Aug. 18—13	25915	190	90	....	572	371	65.	31.	19.5	4.80	4.80	2.40	2.00	.000	.48	194	8.0	4.0	2,750,000	1,050,000	1+	2+	2+	+
Sep. 29—13	26203	100	60	5 S	343	252	20.	27.	18.2	5.28	3.68	2.56	.80	.000	.52	170	....	....	300,000	36,000	1+	2+	2+	+
Jan. 6—14	26810	300	50	4 S	695	513	62.	50.5	28.6	25.6	14.4	6.72	3.20	.051	1.28	270	7.0	4.0	170,000	150,000	1+	2+	2+	+
CHANNEL OPPOSITE PUMPING STATION (3)																								
May 9—13	25233	100	40	1 V	256	144	2.2	11.6	7.5	.098	.098	.44	.28	.002	.48	112	....	....	2,800	175	1+	2+	1+1—	—
June 23—13	25511	90	40	0	255	205	2.	9.3	8.6	.136	.160	.16	.24	.028	.56	126	....	....	440	200	1+	1—1+	2—	+
Aug. 18—13	25911	40	70	1 E	192	....	2.6	9.6	....	.096	....	.36	....	.002	.56	114	....	....	5,000	2,400	1+	2+	2+	+
Sep. 29—13	26200	40	45	2 E	207	175	2.8	9.4	8.8	.000	.088	.352	.288	.000	.44	134	....	....	140	290	1+	2+	2+	+
Jan. 6—14	26811	15	40	1 E	210	....	2.8	8.2	....	.016	....	.272	....	.001	.60	140	....	....	148	148	1+	2+	1+1—	—
RIVER OVER INTAKE CRIB (4)																								
May 9—13	25232	110	35	2 E	259	154	2.8	11.5	7.1	.128	.098	.560	.200	.000	.32	112	....	....	3,400	240	1+	2+	2—	—
June 23—13	25508	95	42	0	290	188	3.	11.2	9.2	.136	.160	.280	.240	.025	.88	128	....	....	9,700	840	1—	1—1+	2—	+
Aug. 18—13	25914	40	70	2 E	196	....	2.	9.7	....	.016	....	.320	....	.000	.24	104	....	....	4,000	3,000	1+	2+	1+1—	+
Sep. 29—13	26199	40	50	1 E	216	183	1.8	9.7	8.7	.024	.000	.344	.240	.000	.52	132	....	....	1,300	1,300	1+	2+	2+	+
Jan. 6—14	26812	30	40	1 E	283	....	13.	8.7	....	.560	....	.432	....	.015	1.0	170	....	....	25,000	10,000	1+	2+	2+	+
RIVER OPPOSITE DIAMOND JO BOATHOUSE (5)																								
May 9—13	25236	60	40	1 V	216	182	4.6	9.0	7.2	.080	.720	.560	.224	.010	.32	118	....	....	5,100	380	1+	2+	2+	+
June 23—13	25509	80	50	0	267	190	2.4	8.6	8.3	.320	.112	.256	.256	.040	.44	128	....	....	1,030	600	1—	1—1+	1—1+	+
Aug. 18—13	25913	50	70	2 E	180	....	2.6	9.7	....	.016	....	.360	....	.002	1.00	112	....	....	16,500	16,000	1+	2+	1+1—	+
Sep. 29—13	26204	45	35	1 E	210	195	3.	10.2	9.0	.000	.040	.352	.272	.000	.24	136	....	....	1,100	560	1+	2+	2+	+
Jan. 6—14	26813	15	40	1 E	230	....	3.2	9.1	....	.128	....	.272	....	.002	.60	140	....	....	3,500	950	1+	2+	2+	+
INTAKE WELL AT PUMPING STATION 6)																								
May 9—13	25237	60	40	1 E	266	141	3.2	11.4	9.5	.080	.144	.360	.200	.001	.32	116	....	....	5,200	225	1+	2+	2+	+
June 23—13	25506	100	45	0	327	253	2.8	9.8	7.8	.144	.104	.320	.096	.032	.48	126	....	....	1,750	1,200	1—	1+1—	2+	+
Aug. 18—13	25912	40	70	1 E	230	....	2.6	9.7	....	.048	....	.280	....	.002	.24	96	....	....	33,000	19,250	1+	2+	1+1—	+
Sep. 30—13	26201	45	40	1 E	208	198	2.8	9.5	8.8	.000	.040	.352	.320	.000	.24	134	....	....	11,000	460	1+	2+	2+	+



Map of Mississippi River at Quincy.



Sand Bar in Mississippi River at Quincy.

water conditions. The water at the time was at the low water stage and a sand bar, as seen in the photograph, extended for a long distance down stream from the intake crib, cutting off the water of the main channel from the intake crib. The Water Company, in order to get as much river water as possible, had cut a channel through the sand bar through which water was flowing into the lower part of Quincy Bay. The water works officials realize the situation and are taking steps to construct a new intake at a more favorable position.

The effect of the sewage from the Broadway *sewer* upon the water at the intake was demonstrated on Feb. 6 when a large fire in a laundry located near Broadway, occurred. During the fire a considerable amount of disinfectant was released and flowed into the sewer. The fire broke out at 4:00 a. m. At noon, eight hours after the release of the disinfectant, a taste and odor became evident in the water. Investigation by the Water Company officials demonstrated that the only source of this taste and odor was the disinfectant emptied into the Broadway sewer. Owing to the direction of the wind at the time it was evidently pretty thoroughly distributed into the lower part of Quincy Bay and portions of it were evidently mixed with the water which entered the intake.

While the Water Company officials and the city officials are not especially proud of the conditions, nevertheless such an excellent demonstration of the possibility of sewage entering an intake should be described for the benefit of those who may be affected by similar conditions. This experience suggests the possibility of using similar material to determine whether pollution from sewers under proper conditions may enter water works intakes.

THE NEWLY REMODELED RESERVOIR.

BY JOHN GAUB*

The reservoir to be described in this paper is known as the Georgetown reservoir and is the second in a series of three reservoirs used for sedimentation purposes at Washington. In shape it is a rectangle comprising about forty-two acres.

This reservoir was originally constructed as a distributing reservoir for the water supply of the District of Columbia. It was intended to divide the reservoir into two sections. The division was to have been made by an embankment, the top of which was to have been at an elevation of two feet below the surface of the water in the reservoir, thus making the upper a sedimentation and the lower section a storage basin where the clear water flowing over the top of the dividing embankment would stand until drawn off for consumpton. This idea, however was not executed, in that the dividing embankment was not built as planned, but was built to the full height of the outside wall and a 48" cast iron pipe line was laid from an opening in the embankment to the effluent gatehouse. By this arrangement water could be drawn from the lower section after having passed through both sections, or it could be drawn directly from the upper section through the cast iron pipe line without passing through the lower section.

The draft through the opening was so great that in times of high turbidity, the muddy water did not diffuse through the whole body of water in the reservoir as was expected, so when the filtration plant was put into operation in 1905, this reservoir became an intermediate storage basin. The filters reduced the turbidity but did not entirely remove it at all times, as some of the silt in the Potomac water is in a colloidal suspension and is not completely caught by the sand of the beds when the water is extremely turbid.

Hence, it was found advisable to try a coagulent as recommended by Messrs. Hering, Fuller and Hazen in their report which led to the adoption of slow-sand filtration for the Washington water-supply. In 1908 Mr. Longley reported a series of experiments on the preliminary treatment of the water after a storage of three days. He concluded that "The desired improvement in the water can be effected by occasional coagulation, with subsequent thorough sedimentation. This process

*Chemist, Filtration Plant, Washington, D. C.

is so entirely flexible that with its use the final product of the filters so much desired is assured."

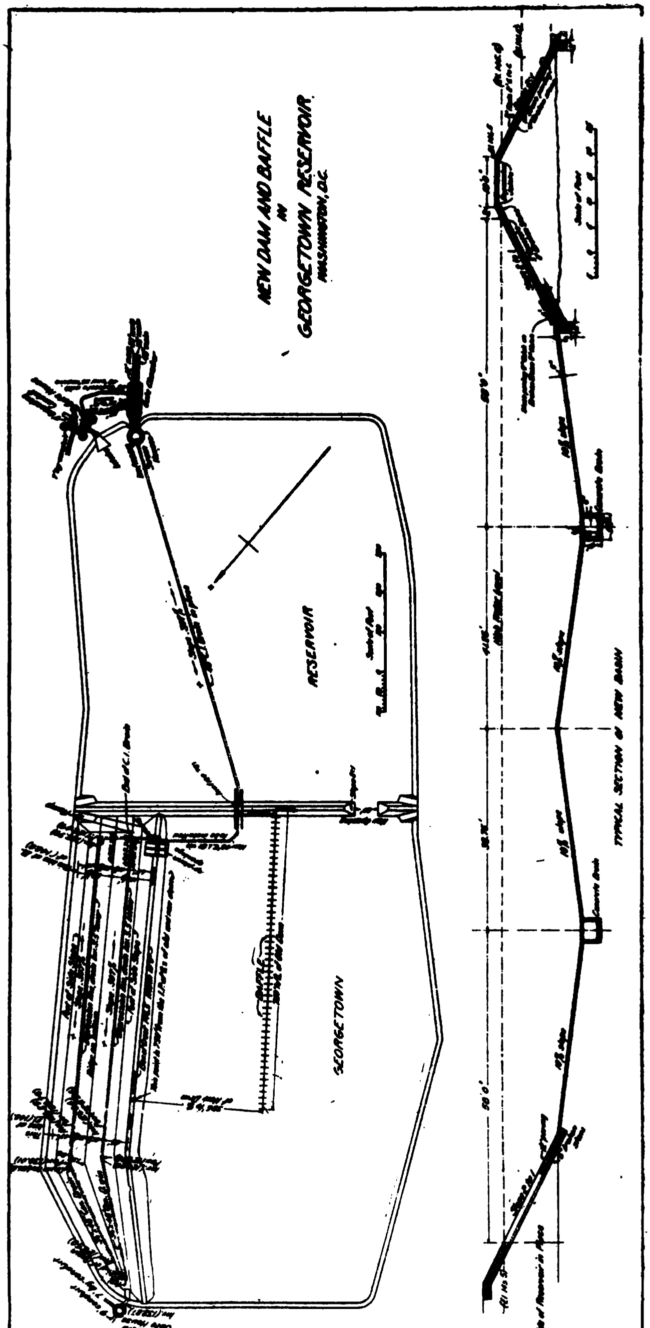
In 1910 Congress appropriated money for the construction of a plant for the application of a coagulant at certain times in order to reduce the turbidity of the water. This plant was constructed on the line of the conduit below the first reservoir. This made the remodelling of the Georgetown reservoir necessary, since conditions favorable to sedimentation must exist in order to get the full benefit of the coagulant. In 1912 and 1913 Congress made another appropriation for the remodelling of the reservoir. This work made the following changes possible; (a) closing of the opening in the middle dam, (b) construction of an opening near the southern end of the dam, (c) the erection of an earthen dam starting from the upper end of the reservoir near the influent gate and running in a line perpendicular to the cross dam until it intersects the latter, thus making a sedimentation basin; (d) the construction of a cut in the lower end of the new dam, containing eight sluice gates; (e) paving the top and sides of the earthen dam with concrete; (f) the construction of two longitudinal drains, of concrete, from the inlet to the outlet of the basin; (g) paving of the basin with concrete; (h) construction of a concrete baffle parallel to the new dam in the middle of the upper section of the reservoir, but not in the sedimentation basin.

The baffle consists of open reenforced concrete triangular piers spaced 15′ apart and connected by a thin concrete wall or web. The piers were amde by placing the reenforcement and concrete forms in the usual way while the web was made by shooting mortar against the wooden forms placed behind the outer layer of wire fabric reenforcement until the web was about four inches thick.

The changes described above will cause the coagulated water to enter the sedimentation basin through the influent gate and to remain long enough to complete the coagulating action and to deposit the greater part of coagulated matter upon the concrete floor of the basin. The sluice gates will be of great assistance in that the water may be drawn into that part of the upper section of the reservoir outside the sedimentation basin, either from near the surface or from near the bottom.

Before the water emerges from the reservoir, it travels around the ends of the baffle and through the old cross dam which originally divided the reservoir into two parts. It is thought that by this arrangement the water will have more time for depositing its turbidity.

In cleaning the sedimentation basin, the sluice gates are closed and the gate leading to the drain is opened. Such of the sediment as will not flow off with the water into the drain is carried out by flushing with fire hose.



Changes in Reservoir.

THE EFFICIENCY OF CLARIFICATION.

Mr. Monfort has so ably discussed the various factors affecting the clarification in sedimentation basins in his paper on "The Efficiency of Sedimentation Basins" that it will not be necessary for me to go into detail. However, since, in general, the efficiency is determined from the removal of turbidity and bacteria, I have prepared several tables in which the removal of turbidity and bacteria are compared before and after the changes herein described were completed.

TABLE 1a.

PERCENTAGE TURBIDITY REMOVED.

Raw Water	Percentage Removed by 1st Res.	Percentage Removed by Un-Imp. Res.	Percentage Removed by 3rd Res.	Total
9	0	0	22	22
75	56	12	10	78
100	75	5	6	86
145	62	3	10	75
200	64	—5	9	68
300	83	0	6	89
600	84	12	2	98
Total	424	27	65	516
Average	61	4	9	74

TABLE 1b.

PERCENTAGE TURBIDITY REMOVED.

Raw Water	Percentage Removed by 1st Res.	Percentage Removed by Imp. Res.	Percentage Removed by 3rd Res.	Total
115	68	14	10	92
150	86	5	3	94
150	76	15	4	95
190	74	16	6	96
230	79	14	2	95
260	71	15	8	94
Total	454	79	33	566
Average	76	13	5	94

TABLE 2a.

PERCENTAGE BACTERIA REMOVED.

Count in Raw Water	Percentage Removed by 1st Res.	Percentage Removed by Un-imp. Res.	Percentage Removed by 3rd Res.	Total
12000	49	9	19	77
11000	23	—7	51	67
780	2	52	24	78

11000	76	9	9	94
45000	21	10	30	61
12300	23	12	25	60
18200	27	54	7	88
Total	221	139	165	525
Average	32	20	23	75

TABLE 2b.

PERCENTAGE BACTERIA REMOVED.

Count in Raw Water	Percentage Removed by 1st Res.	Percentage Removed by Imp. Res.	Percentage Removed by 3rd Res.	Total
8900	53	30	5	88
7700	80	4	10	94
4700	70	18	6	94
920	50	30	10	90
1000	51	39	16	96
3400	44	35	9	88
Total	348	156	56	550
Average	58	26	9	93

In these tables I attempted to show data corresponding with all conditions possible. Since Mr. Monfort has discussed these and they are practically the same for our reservoirs, I will not discuss them. However, it is easily seen from both tables on comparison that the total purification both bacterially and physically has increased in the reservoir due to the improvement and that not so much purification takes place in the third reservoir as formerly. However, this does and should not discourage the use of the third reservoir, for it is a great aid in the chemical purification, not only this but it will be a safe guard in case too much alum should have been added to the water, thus enabling a thorough settling of the coagulant before the water goes to the beds, thus enabling the consumer to get a water absolutely free from alum, but somewhat harder than in former times.

From the data so far at hand this reservoir has proven itself beyond expectation for the following reasons;—(1) increase of twenty percent in total sedimentation and removal of bacteria, (2) makes the third reservoir a safety reservoir for the complete settling of the aluminum hydrate, (3) makes the water harder which is a disadvantage. However, the hardness will not be increased more than that in the water of corresponding communities using the Mechanical process and having water of about the same hardness.

There is no doubt that this improvement has been a very beneficial one, and one which will not be regretted in the future.

A SANITARY SURVEY OF THE OHIO RIVER.

An outline of the work being carried on by the United States Public Health Service.

BY W. H. FROST.

The work which forms the subject of this paper being as yet, only in the process of development, it will be impossible at this time to do more than give a general outline of the plan and scope of an investigation, which is, for the most part, still in the future, without attempting to present the fragmentary data so far collected.

By act of Congress approved August 14, 1912, the name of the Public Health and Marine-Hospital Service of the United States was changed to the Public Health Service, and the scope of the Service materially broadened, especially by a provision adding to the functions of the Service investigations of "The diseases of man and the conditions influencing the propagation and spread thereof, including sanitation and sewage, and the pollution, either directly or indirectly, of the navigable lakes and streams of the United States". The following year Congress included in its appropriation for the work of the Service a sum of $200,000 for special field investigations of public health matters. Under this authorization and appropriation the Service has taken up during the current fiscal year an extensive program of field investigations, including among other things studies of the pollution of navigable waters. These latter studies have been concentrated upon two rivers, the Potomac and the Ohio; the former, representative of the conditions encountered in large tidal streams, and the latter, from the standpoint of the public health, being probably the most important of the large inland streams of the country. The investigations undertaken upon the Potomac and the Ohio rivers, respectively, though concerned with problems which are in many respects different, have been co-ordinated as far as possible; and both have been planned in the hope that they will lead to results and conclusions which will be applicable not only to the particular streams studied, but, with due allowances, to other streams.

Briefly stated, the scope of the work which has been undertaken upon the Ohio River is to determine the extent and character of the existing pollution of the river and its immediate and remote effects upon the stream, and the communities bordering upon it, keeping in

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mind always that the primary object of the whole study is to determine the effects upon the public health, but realizing at the same time that the study must be broad enough to give due weight to the many economic factors which may exert a powerful though indirect influence upon the public health, and that it must be deep enough not merely to furnish a record of existing conditions and effects, but also to go into the fundamental underlying principles in such a way as to throw some light upon what may be expected in the future and what measures of prevention are indicated. With these objects in view the investigation has been planned with special reference to the study of such problems as are general, not local, laying more emphasis upon a broad study of the problems attacked than upon an attempt to take up the problems presented.

The preliminary plans were made with the assistance and counsel of the Advisory Board of the Hygienic Laboratory, especially of Professor Wm. T. Sedgwick, the member of the Board most intimately in touch with such work. Then, as the first step in beginning the study, a visit was paid to the public health authorities of each state bordering upon the Ohio River, to obtain their advice and enlist their active cooperation, which, needless to say, has been freely given.

On account of the necessity of building up an organization from rather widely scattered sources, molding together a personnel of quite different previous training and no previous association, and establishing and equipping the necessary laboratories, it was found that the most efficient method was to develop the work gradually, building up an organization only so fast as it could be utilized along the most effective lines. Upon this plan work was started in July, 1913, with a very small force which has been gradually increased from time to time, with the expectation of having it completed by the latter part of this spring to push intensive field work during the coming summer.

Cincinnati, being the most convenient central point upon the river, was selected as headquarters. A station has been established there for all administrative work, including the equipment of the sub-stations and supplying them with all materials, including culture media for bacteriological work and standards for chemical tests. At this station the general data are compiled and all records of the sub-stations received and compiled. A central laboratory has been equipped there, not only for the necessary work in the vicinity of Cincinnati, but likewise for such special work as can not economically be done at the sub-stations with their less complete equipment, especially for making such chemical examinations as need not of necessity be made immediately, and for intensive study of some special problems in stream purification.

Branch laboratories, fully co-ordinated with the central station, have been established at Pittsburgh, Pa., the head of the river and

presumably the site of its maximum pollution; Portsmouth, Ohio, the last point of any considerable direct sewage-pollution next above Cincinnati; and Louisville, Ky., the next important point of pollution below Cincinnati, and the third largest city upon the river. Additional laboratories are now being equiped at Wheeling, W. Va., and Paducah, Ky., the former city having been selected as being the next large city below Pittsburg to take its water supply from the Ohio and to contribute its sewage thereto, and Paducah as affording the most convenient base from which at the same time to study the conditions existing upon the lower river and to reach the two largest tributaries, the Tennessee and Cumberland. The plans contemplate the establishment of two additional laboratories, upon house-boats, affording bases for a sanitary survey of Ohio River communities and studies of municipal water-supplies, and, at the same time, for studies of the river at points intermediate between the fixed laboratories.

The organization for the investigation, now practically completed, is as follows: Professor E. B. Phelps, Chief of the Division of Chemistry of the Hygienic Laboratory of the Service, though not permanently assigned to this work, is detailed, as consultant, to visit the stations at intervals, to assist in laying out the plans and interpreting the results.

The personnel of the central station at Cincinnati consists of a medical officer of the Service, in general charge of the work; a junior medical officer in direct charge of the bacteriological laboratory at Cincinnati and assisting in administration; three sanitary engineers, of whom one is in charge of the chemical laboratory work while the other two divide between them the work of collecting geographic, hydrographic, population and sewerage data, being, in fact, responsible for the varied sanitary engineering work in connection with the investigation; from two to four technical assistants with chemical and bacteriological training to perform the laboratory work; a pharmacist of the Service to assist in administrative work; and the necessary force of attendants.

The laboratory at Pittsburgh, the most important of the substations, is in charge of a medical officer of the Service, who will, during the summer months, be assisted by a technical assistant. Of the remaining branch laboratories, one is in charge of a medical officer, and one in charge of a technical assistant. In general, the plan followed is to have the branch laboratories established and organized by medical officers, then placed in charge of technical assistants who have previously spent sufficient time in the Cincinnati laboratory to thoroughly acquire the exact technique used there. The plan of having all men in charge of branch laboratories assigned first to the central laboratory at Cincinnati has appeared the only practicable method of attaining the requisite uniformity in details of technique, especially

bacteriological technique. The necessary staff of attendants is, of course, provided at each station. At Pittsburgh and Louisville the laboratories have been located in Marine Hospitals. At the other stations it has been necessary to obtain temporary quarters and equip them for laboratories.

At each station samples are collected daily (or as nearly so as weather conditions will permit) from carefully selected cross-sections of the river, the collections being made by means of launches or, in some instances, from skiffs. Under favorable weather conditions it is possible to cover in this way a stretch of some twenty miles or more of river at each station, and in addition, to obtain samples from a number of important tributaries at their mouths.

The bacteriological examination of each sample consists of total counts on agar at 37°C and gelatine at 20°C, and quantitative estimation of B. Coli by means of fermentation tests in lactose bouillon, confirmed in all instances by plating on lactose media, and, in a definite proportion (10%) of samples, further confirmed by more complete identification of plate colonies. Realizing the extreme difficulty of obtaining comparable bacteriological results at different laboratories, great care has been taken to standardize the procedures followed, in minute detail, and to have all culture media prepared at Cincinnati, and shipped weekly to the branch laboratories.

In addition to this routine a considerable portion of the time to date has been devoted to a comparative study of various methods and media; in fact, during the first few months of laboratory work attention has been devoted more to the selection and standardization of the most suitable procedures than to the attempt to begin at once the accumulation of extensive records.

Chemical studies are for several reasons somewhat less emphasized than bacteriological studies. For one reason, owing to the greater uniformity and permanence of chemical methods, it is possible to compile, from previous records, considerable data as to the chemical constituents of the river water at various points, which is hardly the case as regards bacteriological records. Also, since the results of chemical examinations are less directly applicable to the main problem involved, the sewage pollution of the river, it has not been considered expedient to make the far greater outlay necessary to carry on complete chemical examinations upon the same scale as bacteriological examinations are being made. In such chemical studies as are being made, attention is being devoted especially to studies of dissolved oxygen, extensive work in this direction being under way, parallel with the bacteriological studies. Sanitary and mineral analyses are being made twice weekly upon samples collected from the most important points at each station, and forwarded to the main laboratory at Cincinnati. As soon as it is practicable to do so, more constant and extensive chemical studies will

be undertaken, and special intensive studies of the most important factors at certain points.

Laboratory studies of the stream, must of course, be supplemented by such data as are available through a sanitary survey; and, as above stated, such a survey, to be made probably from houseboats, will be begun in the spring, as soon as the weather will permit. This survey, as at present planned, will be made by two medical officers and two sanitary engineers, one party of a medical officer and a sanitary engineer, being assigned to the upper and one to the lower river. The effort will be made in this survey to obtain, at first-hand, as complete information as is practicable concerning the amount and character of industrial wastes discharged into the main stream; the quality and cost of water supplies obtained from the river and other available sources, and the general sanitary conditions existing in the communities situated upon the river, with special reference to the influence of the pollution of the river upon these conditions. In respect to the larger cities, data collected by state and local officials through a number of years and much more complete than could be collected in this survey are already available, and these are being utilized as far as possible, with the object of so planning any necessary additional studies as to supplement those already made. As supplementary to the sanitary survey, an intensive epidemiologic study of typhoid fever is being made in Portsmouth, Ohio, and vicinity, Portsmouth having been selected as a representative small town, using at present a polluted water supply obtained direct from the Ohio river without purification, and as affording especially advantageous opportunities for study at this time since a filter plant, now in course of construction, is expected to be put into operation within a few months.

Another line of study necessary to check the results of laboratory studies of the stream is a more intensive study of the amount and character of the sewage of the more important cities. Owing to the almost universal lack of interceptors, carrying any large proportion of the mixed sewage of any of the Ohio River cities, sewage analyses must necessarily be unsatisfactory, but it is hoped that the results obtained through somewhat fragmentary studies of this character, may, when taken in connection with other general studies, serve as a partial check upon studies of the river itself.

It is, of course, recognized that in attempting to cover such a broad field as the whole Ohio River, it will be impossible, within the space of a year, to do more than obtain a rather general, broad view of the river as a whole. The complexities of the problems involved are almost infinite, appearing more so the more the general problem is studied, and it is to be expected that the present work will reveal numerous special local problems deserving of and requiring further and closer study.

CHARACTER OF ARTESIAN WELL WATERS IN CHICAGO AND VICINITY.

BY C. B. ANDERSON*

The State Geological Survey and the State Water Survey are now engaged in a special study of artesian waters. While carrying on this work the material for this paper was gathered during the Fall of 1913.

There has been a gradual lowering of the artesian water level in this area for the past twenty years, but particularly so during the last five. The wells were flowing in the early nineties, but since then the static head has been decreasing. The artesian water level from the Potsdam series, in the Chicago Stock Yards District at the present time, is about 200 feet below the surface or a static head of 390 or 400 feet above sea level. This lowered water level is probably due to the large number of industrial plants which have had wells drilled in a small area, in recent years, thus causing an excessive drain on the underground water supply.

The conditions which have made possible artesian wells in Chicago and northeastern Illinois are essentially the same as in any other region having such wells. These conditions are: a fairly porous formation outcropping broadly in a region of considerable rainfall, and extending under a region of lesser attitude, also, the porous formation or transmitting medium is overlain by more or less impervious beds. The overlying beds prevent the escape of the waters which the porous rock has collected at the absorbing area, until tapped by drilling. The overlying beds need not be entirely impervious, in fact rarely are, but may be more or less filled with water, so that the downward pressure of the water is as great as the upward pressure of the contained water in the pervious formation. This can only be true when the region is of practically the same elevation as the absorbing area. Such is the case in northern Illinois, where the St. Peter sandstone, which is the source of much artesian water in this region, is overlain by semi-porous limestone beds and glacial deposits of gravel and till. The elevation of this limestone area, however, is practically equal to that of the St. Peter's collecting area.

Three representative logs of wells in the Chicago region have been

*Illinois State Geological Survey.

selected in order to further illustrate the conditions here existing. The Sears-Roebuck well is in the western part of Chicago, while the Chicago and Northwestern Railroad Company well is at Proviso, about twelve miles, a little north of west, from the Sears-Roebuck well. The well at Bensenville has been chosen as typical of the Chicago, Milwaukee, and St. Paul Railway Company wells at this place. Bensenville is approximately four miles, a little west of north, from Proviso.

LOG OF WELL AT SEARS, ROEBUCK & CO., HARVARD AND HOMAN AVE., CHICAGO.
ELEVATION, 590 FEET.

	Thickness Feet	Depth Feet
Quaternary system		
Pleistocene deposits		
Sand and clay, or surface material	18	18
Clay, blue	56	74
Hard pan	3	77
Silurian system		
Niagara limestone		
Limestone, white	126	203
Limestone, yellow	9	212
Limestone, white	39	251
Limestone, dark gray	116	367
Ordovician system		
Maquoketa shale		
Shale, blue	186	553
Galena-Trenton limestone		
Limestone, dark gray	112	665
Limestone, gray	13	678
Limestone	175	853
Limestone, sandy and shaly	5	858
Limestone, shaly	20	878
Limestone	120	998
St. Peter sandstone		
Sandstone	35	1033
Lower Magnesian limestone		
Limestone, gray	113	1146
Limestone, gray	107	1253
Shale, sandy	25	1278
Shale, green, sandy	15	1293
Shale, sandy	5	1298
Limestone	16	1314
Sandstone and shale	14	1328
Shale, sandy and limestone	33	1361
Cambrian system		
Potsdam series		
Sandstone	187	1548
Limestone, gray	10	1558
Shale and limestone	30	1588
Shale	80	[illegible]

	Thickness Feet	Depth Feet
Marl, red	30	1698
Shale and limestone	60	1758
Shale	30	1788
Shale, blue	34	1822
Sandstone	26	1848
Shale	20	1868
Sandstone	182	2050

Log of Chicago and Northwestern Railway Company well No. 3, SE ¼ of NW ¼ sec. 5, T. 39 N., R. 12 E., Proviso Township, Cook County. Elevation 643.6 feet.*

	Thickness Feet	Depth Feet
Quaternary system		
Pleistocene deposits		
Surface material, yellow clay and pebbles	5	5
Clay, gray with pebbles	25	30
Drift till, pebbles	43	73
Silurian system		
Niagara limestone		
Limestone, light gray, dense, fine grained, sub-crystalline	172	245
Ordovician system		
Maquoketa shale		
Shale, bluish gray	233	478
Galena-Trenton limestone		
Dolomite, light gray, fine grained	130	608
Dolomite, powdered, fine grained	77	685
Dolomite, fragmentary, with small amount of rounded quartz grains	125	810
St. Peter sandstone		
Quartz sand, white, clean, well rounded	150	960
Lower Magnesian limestone		
Dolomite and limestone, fine grained, light gray, mixed with fragments of drab shale	70	1030
Dolomite, finely powdered, slight reaction with cold acid	150	1180
Dolomite, gray, finely powdered, mixed with a considerable amount of rounded sand grains. Slight reaction with cold acid	50	1230
Sandstone, brown to pink, fine grained. Larger fragments contain specks of a black mineral, probably hornblende	40	1270
Dolomite, gray, slight reaction with cold acid. Some sand grains	60	1330

*Well drillings studied by Professor T. E. Savage, University of Illinois.

	Thickness Feet	Depth Feet
Cambrian system		
Potsdam series		
Sandstone, quartz, light brown, some finely powdered dolomite	100	1430
Sandstone, pure, cream colored, rounded	95	1525
Sandstone, brown, with finely powdered brown dolomite, fragments of gray chert	15	1540
Dolomite, gray, sub-crystalline, fragments coated with drab-colored shale	60	1600
Shale, calcareous, gray, sandy, considerable reaction with cold acid	165	1765
Sandstone, quartz, coarse, gray, grains considerably rounded	60	1825
Dolomite, light, grayish brown, sandy	5	1830

Log of Chicago, Milwaukee, & St. Paul Railway Co., well No. 2, Bensenville, Illinois. Elevation, 680 feet.

	Feet Thickness	Feet Depth
Pleistocene deposits		
Quaternary system		
Surface sand, gravel and clay	77	77
Silurian system		
Niagara limestone		
Limestone	193	270
Ordovician system		
Maquoketa shale		
Shale, blue	200	470
Galena-Trenton limestone		
Limestone	100	570
Limestone, containing crevices and "caves" slightly	115	585
Limestone	220	805
St. Peter sandstone		
Sandstone	245	1050
Lower Magnesian limestone		
Limestone, sandy	115	1165
"Red-Rock" (probably sandstone)	40	1205
Limestone	25	1230
Shale	2	1232
Limestone	28	1260
Cambrian system		
Potsdam series		
Sandstone	200	1460
Limestone and shale	240	1700
Sandstone	100	1800
Limestone	16	1816
Sandstone, brown	109	1905
Sandstone, red	140	2045
Sandstone, hard, red	141	2184
Sandstone, soft, white	5	2189
Sandstone, hard, red	12	2201

DESCRIPTION OF FORMATIONS.

General Statement. The formations penetrated by boring in the Chicago region include at the surface the glacial deposits of sand, clay, and gravel, and locally some old lake sands. Beneath these lies the Niagara limestone which is exposed at many quarries in the vicinity. The underlying rocks are known only from a study of samples of well drillings, but on account of the large number examined, a good knowledge of their character has been obtained. The formations in the Chicago region are essentially the same as they are in other parts of the State or adjoining states, where they outcrop.

Pleistocene deposits include the glacial drift and also the old lake sands around Chicago. The material consists of sand, gravel, and boulder clay, varying greatly, both in size of the individual constituents and in the different kinds of rock represented. The thickness of this formation is variable, ranging from a very thin covering over the underlying bed rock to a mantle in places over 100 feet thick.

Niagara limestone is generally a rather compact, dense limestone; in places, however, it may be considerably fractured. The color is commonly a light-gray or bluish gray, although white and yellow phases have been found.

The texture, as a rule, is fine grained and sub-crystalline although coarser and non-crystalline variations have been found. The thickness varies from 150 to over 300 feet. with an average of about 250 feet.

Maquoketa shale is a very compact, close-textured, gray or bluish-gray shale. The thickness averages approximately 200 feet. Its extreme compactness and thickness prevents it from being a water-bearing formation and also serves as a dividing plane to separate the waters in the overlying Niagara limestone from those in the underlying Galena-Trenton formation.

Galena-Trenton limestone. The samples of the well-drillings from this horizon indicate a light-gray, fine-grained dolomite or a limestone which contains considerable magnesium carbonate. Some fragments of chert and a small amount of rounded quartz grains have also been found.

St. Peter sandstone. One of the noteworthy characteristics of this formation is its great variation in thickness. In some deep borings, no sandstone whatever, appears to have been found at this horizon. These cases are rare, however, and in some instances may have been due to the fact that the formation was so thin that the well driller did not note its presence. The thickness ranges from 20 feet and less, to over 250 feet in a few places. The average appears to be about 100 feet. The sand which now composes the St. Peter sandstone was deposited upon a very uneven surface, thus accounting for the great variation in

thickness in places not far apart. The same reason will account for the different thicknesses of the Lower Magnesian limestone.

The material of which the St. Peter sandstone is composed is a remarkable pure, siliceous sand. The color is white or a light cream. The individual sand grains are well rounded and worn, thus showing that they had been subjected to much sorting and abrasion before having been deposited.

The St. Peter sandstone is of primary interest because it is one of the main artesian water beds in the Chicago territory. The first wells drilled in this area obtained their water from the St. Peter sandstone. As the wells were few, flowing water could be secured.

Potsdam Series is often spoken of as the Potsdam formation or even the Potsdam sandstone; when the latter term is used it generally means the first, heavy, sandstone member of the Potsdam series. This first sandstone of the series, sometimes called the Madison sandstone, is found in Chicago at a depth of from 1350 to 1400 feet. The color is usually a light brown for the first 100 feet, followed by a cream colored sandstone for another 100 feet. Below the Madison sandstone, which averages 200 feet in thickness, there is a somewhat sandy and shaly dolomitic limestone for another 200 feet. Underlying this limestone, there are other heavy beds of light brown, red, buff, or white, sandstone, alternating with thin beds of dolomite and shale. The sand as a rule is coarser and not as well rounded as that of which the St. Peter formation is composed. Phases of the Potsdam sandstones have been found, however, in which the individual sand grains are considerably rounded.

The Potsdam rocks are the oldest penetrated in the Chicago region and although the maximum thickness is not known, over 1000 feet have been found by drilling.

The chief interest is attached to the Potsdam because it yields by far the greatest amount of artesian water used in the Chicago area.

MINERAL CONTENT OF WATERS.

Analyses of the mineral content of waters from representative wells have been made in the laboratory of the State Water Survey by the rapid method of boiler water analysis used in the laboratory.*

The determinations made include residue on evaporation, nitrates, chlorine, alkalinity, iron, sulphates, magnesium and non-carbonate hardness. The first four determinations are made according to the well known methods. Iron is determined colorimetrically upon a 100 cc. portion. Sulphates are determined gravimetrically upon a 250 cc. portion. Magnesium is determined volumetrically by means of a solution of lime water upon a 100 cc. portion which has been neutralized with sulphuric acid. Non-carbonate hardness is determined volumetrically in

*University of Illinois Bulletin, State Water Survey, Series No. 8, p. 101.

a 200 cc. portion by means of N-20 soda reagent. Hypothetical combinations of ions have been calculated from these results.

ANALYSES OF WATERS CHIEFLY FROM THE ST. PETER SANDSTONE

Location	Chicago Hickory and Bliss Sts.	Chicago 2270 Claybourn Ave.
Owner	American Malting Co.	Northwestern Brewery
Depth	1302 feet	1302 feet
Depth of casing	70+ feet	To bed rock
Amt. pumped. Gal. per min	160	40

DETERMINATIONS MADE. PARTS PER MILLION

Magnesium (Mg) (as $CaCO_3$)	204	192
Iron (Fe)	0.	0.
Nitrate Nitrogen (N)	.00	.52
Nitrate (NO_3)	.00	2.2
Chlorine (Cl)	184	234
Sulphate (SO_4)	638.6	569.9
Residue	1424	1434
Alkalinity (as $CaCO_3$)	220	202
Non-carbonate hardness (as $CaCO_3$)	368	356

HYPOTHETICAL COMBINATIONS. PARTS PER MILLION.

Sodium nitrate ($NaNO_3$)	......	3.0
Sodium chloride (NaCl)	303.6	386.1
Sodium sulphate (Na_2SO_4)	423.4	338.5
Magnesium sulphate ($MgSO_4$)	244.8	230.4
Calcium sulphate ($CaSO_4$)	233.0	223.0
Calcium carbonate ($CaCO_3$)	220	202
Undetermined	9.2	51.0
Total	1424	1434

HYPOTHETICAL COMBINATIONS. GRAINS PER U. S. GALLON.

Sodium nitrate ($NaNO_3$)	......	.17
Sodium chloride (NaCl)	17.70	22.52
Sodium sulphate (Na_2SO_4)	24.68	19.74
Magnesium sulphate ($MgSO_4$)	14.28	13.44
Calcium sulphate ($CaSO_4$)	13.01	13.00
Calcium carbonate ($CaCO_3$)	12.83	11.78
Undetermined	.54	2.97
Total	83.04	83.62

The mineral content of the water from any individual well is influenced by three factors, (1) Amount and condition of preservation of well casing, (2) Rate of pumping, and (3) Depth of well.

(1) The greater number of artesian wells contain only enough

casing to protect them from the caving of any soft formation. The casing as it is thus used is not for the purpose of excluding water.

The usual method of casing is to place heavy, standard, iron pipe down to bed rock, where a tight joint is made, either by driving the pipe, to which an iron shoe is attached, firmly into the rock, or by using cement. A lighter pipe, or the regulation casing, is used to shut off the Maquoketa shale. Another caving formation, immediately below the St. Peter sandstone, usually requires 50 or 60 feet of casing.

All wells cased in this manner obtain their waters from all the water-bearing formations penetrated. As a result, even though a good water-bearing rock may have been struck, the highly mineralized waters from all the other horizons mingle with the better water, so that the final product from the well is still heavily mineralized.

(2) The rate of pumping is also an important factor with wells which contain only the minimum amount of casing. Certain of the upper formations, particularly the Niagara limestone, contain crevices which permit the presence of considerable water.

Therefore, a well cased down to the Niagara Limestone, may obtain a large amount of water derived from the over-lying glacial gravels.

This supply is limited and variable, so that if a deep well is pumped slowly, say 50 gallons per minute and for only 8 or 10 hours a day, the water obtained will partake of the character of the waters from the upper formations, in this case, the Niagara limestone. We may thus have two neighboring wells of the same depth, same amount of casing, and same elevation, but which yield different kinds of water; because from one a much greater amount of water is pumped than from the other.

(3) The depth of a well naturally is one of the important things in determining the character of its waters, because the different formations contain waters of different qualities. The shallow rock wells, which are not artesian in character, are those which draw their water from the Niagara limestone or in a few cases from the Galena-Trenton limestone. The water is not high in mineral content, the total residue being from less than 10, to 20 or more, grains per gallon, the average being about 12 or 15 grains. The mineral matter is generally the carbonate salts of calcium and magnesium in the form of bicarbonates. Calcium carbonate is the principal constituent, while the sulphates are quite low. The water usually contains enough hydrogen sulphide to make the odor noticeable, the amount in one 250 foot well was 2.67 parts per million or .155 grains per gallon.

The analysis of the water from the 650 foot well of the Wrisley Soap Company is given as an example of the water from the deeper rock wells. The well is not deep enough to reach the St. Peter sand-

stone, although, on account of fissures the character of the water may be slightly influenced by water from this formation.

The mineral content of 29.40 grains per gallon is a little high for a shallow rock well, also some magnesium sulphate is present, which may be due to the waters from the Galena-Trenton limestone.

The first main artesian water horizon is the St. Peter sandstone. The water that it contains is highly mineralized, especially with the salts of calcium and magnesium. Two analyses are given as illustrations. These wells, one owned by the American Malting Company, and the other by the Northwestern Brewery, are of the same depth, 1302 feet, and agree remarkably well in regard to the analyses, even though they are two miles apart. The water obtained is not entirely from the St. Peter sandstone, as the wells are about 300 feet deeper than this horizon, however, the greater amount of the water is from this formation and can therefore be considered as fairly representative. The total mineral content is 1434 parts per million or 83.62 grains per gallon, for the Northwestern Brewery's well, and 1424 parts per million or 83.04 grains per gallon for the well at the American Malting Company. The waters are both very hard, sulphate waters; the sulphates of calcium and magnesium averaging together 26.83 gains per gallon, while the total incrusting solids, which includes the salts of calcium and magnesium, averages 39.17 grains per gallon. The alkalies are low, considering the large amount of other salts that are present. The large mineral content of these waters does not permit their use in boilers, as a very hard, compact scale would form in a very short time.

The wells given in the list of representative wells also draw water from the St. Peter sandstone, but they are also of great enough depth to obtain water from the first sandstone member of the Potsdam series. The analyses show a total average residue of 70-75 grains per gallon, thus comparing very closely with the St. Peter sandstone water.

There is a slight decrease in the average amount of calcium and magnesium sulphates, resulting in a lower total residue. This decrease of the amount and kind of mineral content is very probably due to the addition of the waters from the upper member of the Potsdam series. The water from this first Potsdam sandstone has not a low mineral content, but it is enough lower to produce a decreased total mineral residue when the two waters are added.

It is very probable, however, that wells in the Chicago area down to a depth of 1650 feet are influenced to a very large extent by the waters from the St. Peter sandstone, although there is undoubtedly an addition of the amount of water by penetrating the first sandstone of the Potsdam series. The amount of influence that the St. Peter

sandstone has, will depend upon the thickness at this locality and the size of the well.

The effect of poor surface casing and slow rate of pumping is shown in the analysis of the United States Brewery well water. The well in here of sufficient depth to obtain water from the St. Peter sandstone and perhaps also from the first member of the Potsdam series, yet the total mineral residue is only 34.28 grains per gallon, which does not agree with other analyses of waters from the same horizons. It is very likely that considerable surface water or the less-mineralized waters from the Niagara limestone get into the well and thus decreaseing the total mineral residue of the water obtained from the well. The rate of pumping is given as 75 gallons per minute for 10 hrs. per day, but it is probable that this is too high and that 50 gallons is more nearly correct, this would also be a factor in reducing the mineral content. The comparatively high amount of calcium carbonate in proportion to the sulphates would also indicate that considerable of the water came from a limestone, in this case, probably the Niagara limestone.

The waters from the different members of the Potsdam series have only been isolated in a few instances so that it is not possible to make definite statements in regard to their character. There has been collected enough data, however, to show in a general way, the qualities of the waters from a few of the different horizons.

The well of Sears, Roebuck and Company was originally drilled to a depth of 2057 feet, but was later filled in with concrete for 189 feet, leaving a total depth of 1868 feet. The waters from the lower horizon were cut off because they contained too much salt. The analysis here given was taken when the well was filled in to a depth of 1960 feet and the casing extended from the surface down to 1788 feet. The total mineral content of this water was 1770.3 parts per million or 103.25 grains per gallon. The total amount of calcium and magnesium salts was 19.69 grains per gallon, while there was also present 83.56 grains to the gallon of sodium chloride and sulphate. If we compare this water with that from the Consumers Ice Company well, a marked difference is noted. The depths are practically the same, 1960 and 1967 feet, and the total mineral residue differs by only 10 grains per gallon, the Sears, Roebuck water having the greater amount.

The difference in these waters is not so much in the amount of total mineral residue, but in the amounts of the different salts which are present. The Consumers Ice Company's well water contains two and one-half times as much calcium and magnesium sulphates, and only half the amount of alkalies as the Sears, Roebuck water. This difference appears to be due to the fact that the Sears, Roebuck well is cased down to 1788 feet while the Consumers Ice Company well is only cased for 303 feet. As a result the waters from the St. Peter sand-

stone and other formations mingle with those from the first sandstone of the Potsdam series, so that the final water obtained partakes of the nature of the waters from both of these formations. The influence of the St. Peter sandstone seems to be the greater, as the Consumers Ice Company water is more like that from the St. Peter horizon than that from the Potsdam series.

ANALYSES OF WATERS FROM THE POTSDAM SERIES

Location	Owner	Depth. Feet	Depth of Casing. Feet	Amount pumped, Gal. per Min.	Determinations made. Parts per million: Magnesium (Mg) (as $CaCO_3$)	Iron (Fe)	Nitrate Nitrogen (N)	Nitrate (NO_3)	Chlorine (Cl)	Sulphate (SO_4)	Residue	Alkalinity (as $CaCO_3$)	Non-carbonate hardness (as $CaCO_3$)
Proviso, Ill.	Chicago, Northwestern R. R. Company Well no. 1	1825	1551	107	.0	.0	.80	3.5	22	98.3	475	268	—52.0
Do.	Well no. 5	1841	1723	105	.0	.0	.64	2.8	42	41.6	426	268	—156.0
Do.	Well no. 9	1849	1195	93	.0	.0	.16	.7	46	44.8	454	288	—164.0
Do.	Well no. 11	1800*	1200*	100	.0	.0	1.44	6.2	26	37.2	370	244	—140.0
Bensenville, Ill.	Chicago, Milwaukee & St. Paul R. R. Co.	2290	1236	170	.0	.0	.32	1.4	46	45.7	430	268	—160.0

*Approximately.

ANALYSES OF WATERS FROM THE POTSDAM SERIES—Continued

Location	Hypothetical combinations: $NaNO_3$ Parts per million	$NaNO_3$ Grains per U. S. gallon	NaCl Parts per million	NaCl Grains per U. S. gallon	Na_2SO_4 Parts per million	Na_2SO_4 Grains per U. S. gallon	Na_2CO_3 Parts per million	Na_2CO_3 Grains per U. S. gallon	$CaCO_3$ Parts per million	$CaCO_3$ Grains per U. S. gallon	Undet. Parts per million	Undet. Grains per U. S. gallon	Total Parts per million	Total Grains per U. S. gallon
Proviso, Ill.	4.8	.28	36.3	2.12	145.4	8.47	55.1	3.21	216	12.60	28.4	1.66	475.0	28.34
Do.	3.8	.22	69.3	4.04	6.15	3.60	165.4	9.64	112.0	6.53	14.0	.81	426.0	24.84
Do.	1.0	.01	75.9	4.42	66.3	3.86	173.8	10.14	124.0	7.23	13.0	.76	454.0	26.42
Do.	8.5	.49	42.9	2.49	55.0	3.20	148.4	8.65	104.0	6.07	11.2	.65	370.0	21.55
Bensenville, Ill.	1.9	.11	75.9	4.42	67.6	3.93	169.6	9.88	108.0	6.30	7.0	.40	430.0	25.04

ANALYSES OF WATER FROM THE CHICAGO, MILWAUKEE, AND ST. PAUL RAILWAY COMPANY WELLS.

Location of well and Remarks	Oxides	Calcium Carbonate (Grains per U. S. Gal.)		Calcium sulphate (Grains per U. S. Gal.)		Magnesium carbonate (Grains per U. S. Gal.)		Magnesium sulphate (Grains per U. S. Gal.)		Incrusting Solids (Grains per U. S. Gal.)		Alkali carbonate (Grains per U. S. Gal.)		Alkali sulphate (Grains per U. S. Gal.)		Alkali chloride (Grains per U. S. Gal.)		Non incrusting solids (Grains per U. S. Gal.)		Total residue (Grains per U. S. Gal.)	
		*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**	*	**
Well no. 1 at Bensenville, Ill. Sampled while drilling, at depth of 1450 feet. Samples taken Oct. 29, 1912	Undet.	.97	1.95	4.48	3.15	.83	....	....	1.18	6.28	6.28	....	....	6.74	6.74	2.99	2.99	9.73	9.73	16.01	16.01
Well no. 1 at Bensenville. Sampled at depth of 1450 feet, one hour after drilling stopped. Samples taken Oct. 29, 1912	Undet.	2.94	3.26	4.61	4.13	.27	....	....	.44	7.82	7.83	....	....	7.47	7.47	3.38	3.38	10.85	10.85	18.67	18.68
Well no. 1 at Bensenville. Sampled while drilling, at depth of 2030 feet. Samples taken Nov. 23, 1912	Undet.	5.34	5.34	....	....	2.10	2.10	....	....	7.44	7.44	7.81	7.81	10.50	10.50	4.68	4.68	22.90	22.90	30.43	30.43
Well no. 1 at Bensenville. Sampled while drilling, at depth of 2128 feet. Samples taken Nov. 29, 1912	Undet.	6.64	6.64	....	....	2.87	2.87	....	....	9.51	9.51	8.92	8.92	4.82	4.82	12.44	12.44	26.18	26.18	35.69	35.69
Well no. 1 at Bensenville. Samples taken at depth of 2290 feet. Well finished with casing to depth of 1236 feet. Samples taken Dec. 13, 1912	Undet.	10.22	13.12	3.95	....	3.88	1.45	....	3.48	18.05	18.05	....	....	3.17	3.17	50.96	50.96	54.13	54.13	72.18	72.18
Well at Godfrey Yards, near Bensenville. Depth 1833 feet. Well finished with casing to depth of 1196 feet. Samples taken June 28, 1911	Undet.	6.90	6.90	....	....	4.04	4.04	....	....	10.94	10.94	2.97	2.97	11.71	11.71	3.18	3.18	17.86	17.86	28.80	28.80
Same well at Godfrey Yards as preceding. Depth 1833 feet. Sample taken Dec. 30, 1912	Undet.	8.21	8.21	....	....	3.48	3.48	....	....	11.69	11.69	2.77	2.77	45.03	45.03	2.89	2.89	50.69	50.69	62.38	62.38

*Analysis made by the Chicago, Milwaukee and St. Paul Railway Company.
**Recalculation by the State Water Survey.

ANALYSES OF WATERS OF HIGH MINERAL CONTENTS FROM ST. PETER AND POTSDAM HORIZONS. TABLE IIa.‡

Location	Owner	Depth. Feet	Depth of Casing. Feet	Amount pumped: Gal. per Min.	Determinations made. Parts per million: Magnesium (Mg) (as $CaCO_3$)	Iron (Fe)	Nitrate Nitrogen (N)	Nitrate (No_3)	Chlorine (Cl)	Sulphate (SO_4)	Residue	Alkalinity (as $CaCO_3$)	Non-carbonate hardness (as $CaCO_3$)
Chicago 61st St. and University Ave.	Consumers Ice Company	1967	To bed rock	303	184	.4	.80	3.50	230	705.6	1607	214	482
Chicago 312 Fletcher St.	Best Brewery	2013	70	100	100	.8	.20	.90	162	849.7	1740	212	176
Chicago 21st St. and Albany Ave.	Garden City. Brewery	1410	To bed rock	200*	184	1.2	.00	.00	550	347.3	1640	224	340
Chicago 337 Alexander St.	Gottfreid Brewery	1658	70	685	164	.4	.24	1.10	440	550.7	1781	226	372
Chicago 1440 N. Halsted St.	Independent Brewery	2164	81	150*	76	.8	.00	.00	290	868.6	2019	212	152
Chicago 2320 N. Bobey St.	Jefferson Ice Company	1650	To bed rock	250	200	.0	.00	.00	680	605.7	2245	224	440
Chicago North Ave. and Clybourn Ave.	Peter Hand Brewery	1973	50	40	72	.0	.28	1.20	206	890.8	1894	214	136
Chicago 18th St. and Canalport Ave.	Schoenhoffen Brewery	2187	76	100*	136	.0	.24	1.10	620	578.3	2135	240	556
Chicago Howard and Homan Ave.	Sears, Roebuck Company	1960	1788	75	84	.0	.00	.00	530	423	1770	286†	....
Chicago 916 N. Paulina	West Side Brewery	2100	80	180	128	.8	.48	.00	780	679.7	2544	215	296

*Approximately.
†Alkalinity to Phenol-phthalein is 8 parts per million.
‡For hypothetical combinations see Table IIb.

ANALYSES OF WATERS OF HIGH MINERAL CONTENTS FROM ST. PETER AND POTSDAM HORIZONS. TABLE IIb.

Hypothetical combinations

Location	$NaNO_3$		NaCl		Na_2SO_4		$MgSO_4$		$MgCO_3$		$CaSO_4$		$CaCO_3$		$FeCO_3$		Undet.		Total		Remarks
	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	
Chicago 61st St. and University Ave.	4.8	.28	379.5	22.13	360.3	21.02	220.8	12.88	......	......	405.3	23.67	214	12.48	.8	.05	21.5	1.25	1607	93.75	Note high amounts of calcium and magnesium sulphates.***
Chicago 312 Fletcher St.	1.5	.09	267.3	15.57	1006.3	58.69	120.0	7.00	......	......	103.4	6.03	212	12.37	1.7	.10	27.8	1.62	1740	101.47	Note lower amounts of $MgSO_4$ and $CoSO_4$ and large amount of Na_2SO_4.**
Chicago 21st St. and Albany Ave.	......	......	907.6	52	31.5	1.84	220.8	12.88	......	......	212.2	12.37	224	13.06	2.5	.14	41.4	2.41	1640	95.63	Water only slightly affected by the Potsdam series.*
Chicago 337 Alexander St.	1.5	.09	726.1	42.34	287.1	16.75	196.8	11.48	......	......	282.9	16.50	226	13.18	.8	.05	59.8	3.49	1781	103.88	Note effect of excessive pumping in increasing mineral contents of the water.***
Chicago 1440 N. Halsted St.	......	......	478.6	27.95	1069.7	62.38	92.2	5.31	......	......	103.4	6.02	212	12.37	1.7	.10	62.4	3.64	2019	117.77	Note large amount of alkalies and lower amounts of $MgSO_4$ and $CaSO_4$.**
Chicago 2320 N. Robey St.	......	......	1122.1	65.44	272.6	15.90	240	14.00	......	......	326.4	19.03	224	13.07	......	......	59.9	3.49	2245	130.93	Comparative high rate of pumping aids in giving water a high mineral content.***
Chicago North Ave. and Clybourn Ave	1.6	.09	339.9	19.82	1125.4	65.93	86.4	5.04	......	......	87.0	5.07	214	12.48	......	......	39.7	2.31	1894	110.74	Large amount of alkalies indicate Potsdam series.
Chicago 18th St. and Canalport Ave.	1.5	.09	1023.1	59.68	492.8	28.74	163.2	9.51	......	......	163.2	9.51	240	14.0	......	......	51.2	2.98	2135	124.51	do. Note increase of NaCl.
Chicago Howard and Homan Ave.	......	......	874.6	51.02	557.9	32.54	57.6	3.36	30.2	1.75	......	......	250	14.58	......	......	......	......	1770.3	103.25	Large amount of casing excludes St. Peter water. Therefore small amount of $MgSO_4$.**
Chicago 916 N. Paulina	2.1	.12	1287.1	75.05	584.7	34.20	153.6	8.95	......	......	228.9	13.34	......	......	1.7	.10	69.9	4.07	2544	148.43	Note extreme amount of NaCl.** Some effect from St. Peter water.

***Water chiefly from St. Peter sandstone and first member of Potsdam series.

*Water chiefly from St. Peter sandstone.

**Water chiefly from Potsdam series.

ANALYSES OF REPRESENTATIVE WATERS FROM THE CHICAGO AREA. TABLE Ia.**

Location	Owner	Depth. Feet	Depth of Casing. Feet	Amount pumped. Gal. per Min.	Determinations made. Parts per million								
					Magnesium (Mg) (as $CaCO_3$)	Iron (Fe)	Nitrate Nitrogen (N)	Nitrate (No_3)	Chlorine (Cl)	Sulphate (SO_4)	Residue	Alkalinity (as $CaCO_3$)	Non-carbonate hardness (as $CaCO_3$)
Chicago 1249 S. Talman	American Malting Company	1603	571	150	144	.6	.00	.00	150	489.2	1218	228	344
Chicago 1734 Fullerton Ave.	Deering Harvester Company	1565	38	110	148	1.2	.08	.4	226	571.9	1418	220	392
Chicago 445 N. Sacremento Ave.	Griffen Wheel Company	1738	300	175	212	.4	.00	.00	210	564.5	1389	218	344
Chicago 2612 W. 19th St.	Illinois Vinegar Works	1350	To bed rock	150	128	.6	.00	.00	330	332.9	1284	224	196
Chicago 2421 W. 26th St.	Monarch Brewery	1600	To bed rock	115	192	.00	.56	2.5	250	412.4	1253	228	292
Chicago 3937 Wallace St.	Mullen's Brewery	1632	39	68.9	108	.4	.00	.00	120	466.1	1088	214	272
Chicago 1908 W. 18th St.	National Brewery	1590	14	100*	156	1.6	.24	1.1	130	555.8	1217	210	360
Chicago 18 St. and Cannalport Ave.	Schoenhoffen Brewery	1600	76	100*	140	2.0	.00	.00	120	569.1	1289	222	384
Chicago Cottage Grove and 27th St.	Seipp's Brewery	1600	50	200	184	.4	.00	.00	160	625.0	1384	212	440
Chicago 37th St. and Halsted	South Side Brewery	1632	41	100*	164	.00	.00	.00	250	465.8	1368	216	320
Chicago 40th St. and Normal Ave.	Tosetti Brewery	1366	42	60	144	.8	.24	1.1	250	553.7	1456	212	362
Chicago Snow St. and Elston Ave.	United States Brewery	1344	59	75	104	1.2	.24	1.1	40	227.3	588	160	116
Chicago 38th St. and S. Racine	White Eagle Brewery	1816	57	100*	136	.4	.24	1.1	140	517.6	1222	212	362
Chicago 900 S. Fifth Ave	Wrisley Soap Company	650	To bed rock	40	136	1.8	.20	.90	36	138.9	504	242	56

*Approximately.
**For hypothetical combinations see Table Ib.

ANALYSES OF REPRESENTATIVE ARTESIAN WELL WATERS FROM THE CHICAGO AREA. TABLE II.

Hypothetical combinations

Location	$NaNO_3$		NaCl		Na_2SO_4		$MgSO_4$		$MgCO_3$		$CaSO_4$		$CaCO_3$		$FeCO_3$		Undet.		Total		Remarks
	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	Parts per million	Grains per U. S. gallon	
Chicago 1249 S. Talman	....	....	264	15.40	236	13.77	172.8	10.08	....	....	272	15.87	228	13.30	1.2	.07	44	2.57	1218	71.06	Water chiefly from two horizons.*
Chicago 1734 Fulleton Ave.	.5	.03	372.9	21.75	291.4	16.99	177.6	10.35	....	....	331.8	19.36	220	12.83	2.5	.15	21.3	1.24	1418	82.70	Do.
Chicago 445 N. Sacremento Ave.	....	....	346.5	20.21	347.3	20.26	254.4	14.83	....	....	179.5	10.47	218	12.72	.8	.05	42.5	2.48	1389	81.02	Do.
Chicago 2612 W. 19th St.	....	....	544.6	31.79	213.2	12.43	153.6	8.95	....	....	92.5	5.39	224	13.07	1.2	.07	54.9	3.20	1284	75.90	Water chiefly from St. Peter sandstone and Lower Magnesian limestone.
Chicago 2421 W. 26th St.	3.4	.19	412.6	24.03	196.1	11.43	230.4	13.44	....	....	136.0	7.93	228	13.30	....	....	46.5	2.71	1253	73.03	Water chiefly from two horizons.*
Chicago 3937 Wallace St.	....	....	198.0	11.55	303.4	17.69	130.0	7.58	....	....	223.0	13.01	214	12.48	.8	.05	18.8	1.10	1088	63.46	Same as above, but slightly modified by waters from Niagara limestone.
Chicago 1908 W. 18th St.	1.5	.03	214.5	12.67	311.7	18.55	187.2	10.91	....	....	277.4	16.77	210	12.25	3.3	1.9	11.4	.66	1217	71.43	Water chiefly from two horizons.*
Chicago 18th St. and Canalport Ave.	....	....	198.0	11.55	297.6	17.35	168.0	9.80	....	....	331.8	19.36	220	12.95	4.1	.24	67.5	3.94	1289	75.19	Do.
Chicago Cottage Grove and 27th St.	....	....	264.0	15.40	300.3	17.50	220.8	12.87	....	....	348.2	20.30	212	12.37	.8	.04	37.9	2.21	1384	80.69	Do.
Chicago 37th St. and Halsted	....	....	412.6	24.06	235.0	13.71	196.8	11.48	....	....	212.7	12.40	216	12.60	....	....	94.9	5.53	1368	79.78	Do.
Chicago 40th St. and Normal Ave.	1.5	.09	412.6	24.06	305.9	17.84	172.8	10.08	....	....	296.5	17.29	212	12.37	1.6	.09	53.1	3.09	1456	84.90	Do.
Chicago Snow St. and Elston Ave.	1.5	.09	66.0	3.84	171.7	10.01	125.0	7.29	....	....	16.3	.95	160	9.33	2.5	.15	45.0	2.62	588	34.28	Poor casing and slow rate of pumping allows water from Niagara limestone to get into well.
Chicago 38th St. and Racine	1.5	.09	231.0	13.47	252.2	14.70	163.2	9.52	....	....	307.4	17.92	212	12.37	.8	.05	53.9	3.14	1222	71.26	Well is not pumped many hours per day. Shows influence of St. Peter water.
Chicago 900 S. Fifth Ave.	1.2	.07	59.4	3.46	126.0	7.35	67.2	3.92	64.8	3.78	....	....	162	9.45	3.7	.22	19.7	1.15	504	29.40	Note small amounts of sulphates. Water contains considerable hydrogen sulphide.**

*St. Peter sandstone and first member of Potsdam series.

**Water chiefly from Niagara limestone and Galena Trenton limestone.

The deep wells of the Chicago, Milwaukee and St. Paul Railway Company at Bensenville and of the Chicago, Northwestern Railway Company at Proviso, have furnished some very good information in regard to the qualities of the waters from the Potsdam series.

The water from well No. 1 at Bensenville was collected from different depths while the drilling was in progress. The analysis of the water from the 1450 foot horizon indicates a sulphate water but yet not a very hard water, the total mineral residue averaging only 17.34 grains per gallon. This water could be used in boilers with only a slight amount of treatment. The horizon from which this water was obtained is the first member of the Potsdam series, and is reached in Chicago at a depth of about 1350 feet. The water obtained at a depth of 2030 feet shows an increase of about 12 grains per gallon of the alkalies, over the amount present in the water from the 1450 foot level. The amount of incrusting solids remains practically the same, but with a marked difference in that the sulphates of calcium and magnesium are absent; these elements being present in the form of carbonates. Therefore the water at the 2030 foot horizon is a better water because the sulphates of calcium and magnesium which are here absent, tend to form a very hard, compact scale when the water is used in boilers. The great increase in salinity is the conspicuous feature about the water obtained from the 2290 foot horizon as the amount of salt present is over ten times as great as that in the water from the 1450 foot level. There is also an increase in the total amount of incrusting solids to 18.05 grains per gallon; and sulphates of calcium and magnesium are again present. It would therefore be advisable to use some treatment for this water in case it should be used in boilers.

The Chicago, Milwaukee and St. Paul Railway Company have cased these wells down to a depth of 1200-1250 feet, and are thus able to procure a water that can be used in boilers without treatment. The main reason for this is that the very hard, sulphate waters from the St. Peter sandstone have been excluded.

Analyses of the waters from the Proviso wells show a total mineral residue of only 370 to 430 parts per million or 20 to 28 grains per gallon, and no sulphates of calcium and magnesium. As these wells are cased to 1700 feet, the effect of shutting off the St. Peter sandstone water is shown.

In closing, I wish to ask your assistance and cooperation in this study of deep wells that is being conducted by the state Geological and State Water Surveys. The work can only be made a success, by securing the assistance of men who have specific knowledge concerning wells. We therefore respectfully ask for any information that you may have regarding wells, such as location, records of drilling, kind and amount of water obtained. This help will be greatly appreciated

as an aid in securing accurate knowledge of the underground water conditions in this state.

DISCUSSION.

Pownall: Does the section apply around Joliet? Also how deep is the St. Peters formation at Chicago? Has anyone had experience in plugging wells with concrete.

Anderson, C. B.: The formations would be found at a greater depth in Chicago as there is a slight local dip of about 8 to 10 feet to the mile from Joliet to Chicago. The geological column at Joliet is otherwise the same as at Chicago. The State Geological Survey has a good record of a well at Joliet, if desired a complete log will be sent. The St. Peter sandstone is found in Chicago at an average depth of about 900 feet.

In certain instances wells have been plugged with cement.

Pownall: Was that plugging done by simply pouring concrete in?

Anderson: The concrete is generally mixed and placed in small bags before putting it into the well.

Bardwell: We had a little experience about three months ago with a 130 ft. well. We tried to plug out the strong salt water. We first tried concrete, one part cement and one part sand and it did not do any good. We drilled that out, drilling below the 100 ft. mark where the salt water was. We tried other means without success and would be glad to know of successful plugging.

Anderson: Wooden plugs from 2 to 3 feet in length and of nearly the same diameter as the well are sometimes used for plugging. The plugs being driven into place by means of heavy rams. It is usual to place a few feet of coarse, broken rock above the plug.

Anderson, W. F.: We had some experience with a 10" well at Hammond, La. We thought there was some obstruction at the bottom of the well and we took a photograph. This we did by shaping a wooden plug to a size that would enter the casing. From this plug a tin band extended 2" downward enclosing a space in which a number of nails were driven leaving the heads flush with the outer edge of the tin band. In this space soap was smoothly packed so as to take an impression of any object. The plug was then lowered into the well and an impression obtained. It was found that a 4" pipe had been dropped in the well and was leaning to one side of the casing. The pipe was taken out, the sand removed from the bottom of the well, after which a bag of oatmeal was put in. When the oatmeal swelled it shut off the water and sand sufficiently to let the cement set.

Anderson, C. B.: Flax seed is often used the same way.

THE ECONOMIC DESIGN OF STORAGE TANKS.

BY HAROLD E. BABBITT*

In laying out water works systems the condition frequently arises that a storage or pressure tank or a tank combining these two features is needed. The factors that determine the location and capacity of such tanks are very numerous, and generally speaking, depend upon practical local considerations. Once the capacity of the tank has been decided upon and a site chosen therefor, whether this be on a hilltop, a tower or a building, it becomes of interest to ascertain the most economical proportions for such a tank. It is the object of this paper to present a mathematical analysis of a general character which brings out the economical relation between depth and diameter. This analysis indicates that for any given cost of material of construction, there is a fixed depth for all tanks regardless of their capacity and that the economical way to secure increased capacity is to increase the diameter while maintaining the depth the same.

In demonstrating this proposition the depth of the tank may be expressed by the formula

$$h = \sqrt{\frac{1354fcMrf_t e}{316wMarK + bf_t en}}$$

in which;

a, is the fraction which t′ is of t. The considering of this factor as a constant may be open to some criticism, as it is dependent on the minimum thickness of plate used and the frequency of increase in thickness of the plates. With a standard practice it is closely correct and from a theoretical viewpoint absolutely correct.

b, cost in cents of pumping one million gallons of water one foot high.

c, the cost of the foundation in dollars per cubic yard assuming a concrete foundation or in dollars per unit area under the assumption that the cost of foundation is a function of the area.

d, the diameter of the tank in feet.

e, the average efficiency of vertical joints.

f, the depth of the foundation in feet. If the tank is constructed on a tower with pile or concrete post foundation the expression is simply modified to suit this condition.

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f_t, the working strength of the metal in tension in pounds per square inch.

h, the depth of the tank in feet.

K, cost of metal in cents per pound.

M, a factor covering labor, erection, overhead charges, etc., and approximately a certain fraction of the cost of metal and foundation.

n, the number of times per day the tank is filled by pumping.

Q, the capacity of the tank in cubic feet.

r, the annual rate of interest plus depreciation on the extra initial cost of the tank to decrease the pumping cost. The initial cost of the tank itself is rendered somewhat greater than otherwise by a decrease in the depth in order to reduce the cost of pumping.

t, the thickness of the metal of the lowest side plate in inches.

t′, the average thickness of the metal in inches.

W, total weight of metal in pounds.

w, weight of metal in pounds per cubic foot.

The total cost of the tank can then be expressed as the sum of the cost of the metal and foundation times M plus the capitalized cost of pumping. The daily cost of filling the tank is

$$\frac{Qb\,hn}{13{,}333{,}333}\text{dollars.}$$

The amount which should be set aside as the cost of tank to cover pumpage is therefore

$$\frac{365\,Qb\,hn}{r(13{,}333{,}333)}\text{dollars.}$$

The total cost in dollars is thus

$$M\left[\frac{WK}{100}+\frac{d^2fc\pi}{108}\right]+\frac{365Qbhn}{r(13{,}333{,}333)}$$

The term $\frac{\pi d^2 fc}{108}$ is obtained on the supposition that the foundation is a solid concrete block. If a tower, piles or concrete piers are used a modification of the formula is simple. To express W in terms of h and d it is known that

$$t=\frac{2.6\,hd}{f_t e}$$

and thus

$$t'=\frac{2.6\,ahd}{f_t e}$$

and the volume of the steel is equal to

$$\frac{2.6\,h^2d^2a\pi}{12\,f_te}$$

Therefore

$$W = \frac{2.6\,h^2d^2aw\pi}{12\,f_te}$$

and the cost of the pipe in dollars becomes

$$\frac{2.6\pi h^2d^2awKM}{1200f_te} + \frac{\pi d^2fcM}{108} + \frac{365\,Qbhn}{r(13{,}333{,}333)} \text{ dollars.}$$

We thus have the expression of the cost in two variables, h and d, such that $\frac{\pi d^2h}{4} = Q$ a constant for any given capacity. The cost of the tank can be reexpressed as

$$\frac{.00681\,hwK4QMa}{f_te\pi} + \frac{.0291\,fc4QM}{\pi h} + \frac{365\,bhQn}{r(13{,}333{,}333)} \text{dollars.}$$

Differentiating this with respect to h and equating the derivative to zero we find that

$$h = \sqrt{\frac{1354\,fcMrf_te}{316wMarK + bf_ten}}$$

a constant independent of the capacity of the tank.

For example let it be supposed that a tank of 50,000 gallons capacity is to be constructed in such a manner that the average thickness of the metal of the sides of the tank is 67% of the thickness of the metal in the lowest side plate i.e. a is 0.67, the cost of pumping one million gallons one foot high is 10c, equal to b, the cost of concrete in the foundation is $5.00 per cubic yard, the efficiency of the vertical joints in the tank will average 67%, the depth of the concrete foundation is 5 feet, the cost of the metal K is 5c per pound, the labor, erection, overhead charges, etc., are 10% of the original cost of the tank or M is 1.1, the tank is to be filled and emptied once a day or n equals 1, the rate of interest plus depreciation is 10% or r equals 0.10, the

working strength of the metal f_t is 12,000 pounds per sq. inch and the value of w or the weight of metal per cubic foot is 490 pounds.

Substituting these values in the above expression it becomes apparent that the depth of the tank should be 15 feet. If the cost of pumping is not considered the most economical depth of tank would be 23 feet. The depth of the tank is unaffected whether for 50,000 gallons or 50,000,000 gallons so that all tanks should theoretically have the same depth with the same unit costs of materials. A slight change in the cost of materials or pumping, however, may affect the depth of tank materially.

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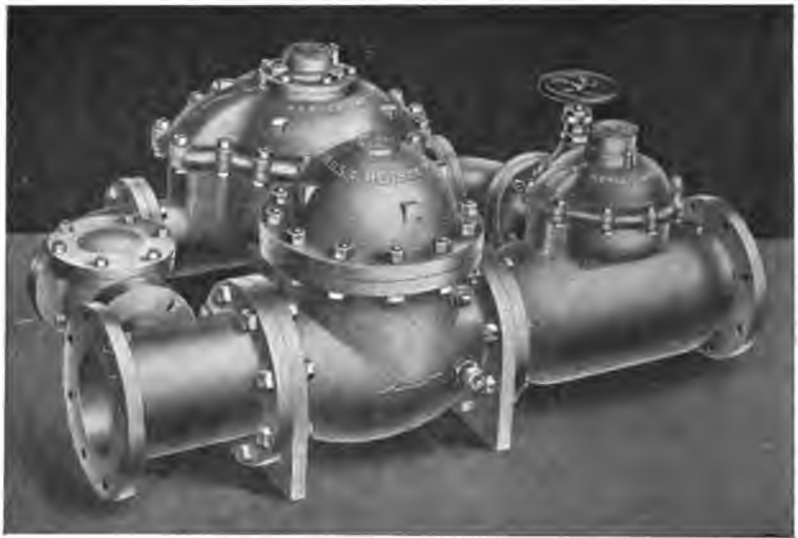

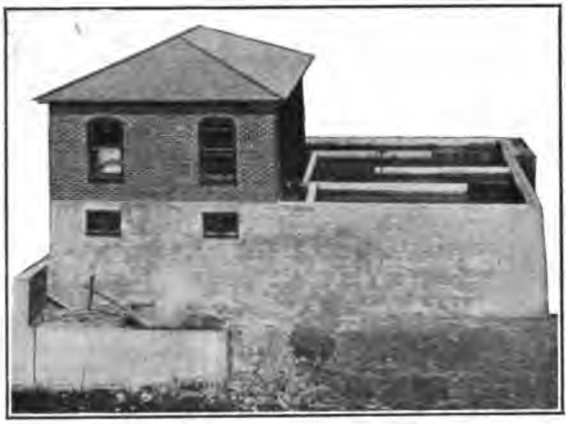

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